Factors for Success in Electronic Health Record Implementation:

Literature Review and Key Considerations

Office of the Nursing & Midwifery Services Director

HSE Seirbhís Sláinte Níos Fearr á Forbairt | Building a Better Health Service

UCD DUBLIN

Insight Centre for Data Analytics
A world leading SFI Research Centre

Foreword

Welcome to this report *Factors for Success in Electronic Health Record (EHR) Implementation: Literature Review and Key Considerations* which highlights the key factors for successful EHR implementation. This report was commissioned by the Office of the Nursing and Midwifery Services Director, Health Service Executive to support services who are or will be embarking on the digital transformation journey of implementing an EHR.

The report highlights fifteen key factors under the categories organisational, human and technological. It acknowledges the importance of each of the key factors in successful EHR implementation in addition to outlining twenty-five key considerations.

The success factors and key considerations are drawn from an extensive international literature review; a review of national literature that includes grey literature; and the experiences of our colleagues on the Advisory Group who have engaged with or worked on digital transformation projects across Ireland.

The Advisory group were fundamental to driving, reviewing and providing direction for this work. Their combined experience and insights added considerable value to this report and more specifically the derivation of the key considerations. Thank you for your time, energy and commitment.

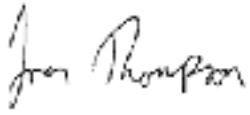
We would like to thank Dr Orna Fennelly, who authored this report for her expertise, dedication and commitment in completing this important piece of work. In addition, we would like to thank her colleagues in UCD, in particular Dr Catriona Cunningham and Professor Neil O'Hare for their support and guidance to Orna.

Sláintecare outlines clear goals for the eHealth agenda to both digitally connect the health service and digitally connect the citizen (to health). The EHR is the cornerstone of this Programme. We hope this document will be of value to clinicians, managers and technicians alike to provide meaningful information and offer key insights into EHR implementation as we go forward.

Getting EHR implementation right is about helping health and social care professionals provide safe quality care, improve efficiency and healthcare outcomes for people that use our services. It's also about empowering and enabling people who use our services to experience better care.

Loretto Grogan

National Clinical Information Officer for Nursing and Midwifery, ONMSD



Fran Thompson

Chief Information Officer, Interim, HSE

Prof. Neil O'Hare

Group CIO, Ireland East Hospital Group; Prof. Health Informatics, School of Public Health, Physiotherapy and Sports Science, UCD

Author and Advisory Group

Authored by:

Dr. Orna Fennelly	School of Public Health, Physiotherapy and Sports Science, and the Insight Centre for Data Analytics, University College Dublin (UCD)

Advisory Group Members:

Jason Chandler	Information Communication Technology (ICT) Project Manager, Office of the Chief Information Officer, Health Service Executive (HSE)
Dr. Heather Cronin	Senior Clinical Psychologist in Neuropsychology and Clinical Health and Social Care Professions (HSCP) Lead, Clinical Management System for Specialised Care Services, National Rehabilitation Hospital (NRH).
Dr. Caitriona Cunningham	Associate Professor, School of Public Health, Physiotherapy and Sports Science, UCD.
Rita Darcy	Community Electronic Health Record (EHR) Senior Project Manager, HSE
Loretto Grogan	Chair of Advisory Group and National Clinical Information Officer for Nursing and Midwifery, HSE
Fiona Lawlor	Business Manager with the National Project Team on the Maternal and Newborn-Clinical Management System (MN-CMS) project.
Prof. Neil O'Hare	Prof. of Health Informatics, School of Public Health, Physiotherapy and Sports Science, UCD and Group Chief Information Officer, Ireland East Hospital Group
Dr. Conor O'Shea	General Practitioner and National Co-ordinator of the General Practice Information Technology (GPIT) Project at the Irish College of General Practitioners (ICGP)
Angela Reed	Senior Professional Officer, Northern Ireland Practice and Education Council for Nursing and Midwifery (NIPEC).
Miriam Roche	Electronic Patient Record (EPR) Project Manager, St. James' Hospital (SJH)

Glossary of terms

Term:	Definition:
Adaptability	Flexibility in the software to enable customisation
Artificial Intelligence (AI)	Systems which interpret data, reasons through the knowledge derived from this data, decides the best action(s) to take (according to pre-defined parameters) to achieve a given goal and learns to adapt its behaviour by analysing how the environment was affected by previous actions
Burnout	Feelings of energy depletion or exhaustion, negativism or cynicism related to one's job and/or mental distance from one's job
Champion	End-user who operates in a liaison role between other end-users and IT staff
Clinical Decision Support (CDS)	Software which matches the characteristics of an individual patient to a computerised clinical knowledge base, and patient-specific assessments or recommendations are then presented to the clinician to aid decision-making
Electronic Health Record (EHR)	**Longitudinal record of information regarding the health status of a subject of care which follows them from one practice or specialist to the next, in computer processible form**
Electronic Patient Record (EPR) / Electronic Medical Record (EMR)	Longitudinal record of health information within a single institution
End-user	Person accessing and using the EHR system
Front-line staff	Person interacting with health-service users
General Practitioner (GP)	Medical doctor based in the community who assesses and treats acute and chronic illnesses and provides preventive care and health education to patients
Go Live	Point at which EHR becomes operational
Healthcare Information and Management Systems Society (HIMSS)	A global, not-for-profit organisations focused on better health through information and technology
Health Information Quality Authority (HIQA)	An independent authority that exists to improve health and social care services for the people of Ireland
Healthcare organisation	Utilised throughout the report to describe all facilities which provide health services
Healthcare professional (HCP)	Provider of healthcare who may be from any discipline including medicine, nursing, midwifery, pharmacy, allied health professionals etc.
Health information exchange (HIE)	Sharing of patient data across organisational and geographical boundaries
Health Information Technology for Economic and Clinical Health (HITECH)	An Act in the United States (US) which provided monetary incentives to HCPs who demonstrated meaningful use of EHRs (i.e., CDS, HIE)
Information Communication Technology (ICT)	An extension of the term information technology (IT) that stresses the role of communication
Internet of things (IoT)	System of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.
Interoperability	Ability of different information systems, devices or applications to connect and 'talk' effectively to one another in a coordinated manner, within and across organisational boundaries
KLAS	An organisation which conducts research on health information technology to provide accurate, honest and impartial insights by building relationships with the buyers and sellers
Natural Language Processing (NLP)	Application of computational techniques to analysis and synthesis natural language.
Patient	Utilised in this report to describe a person using health services
Patient Portal	Comprises healthcare information documented and managed by a healthcare organisation only and may fall under the umbrella of a PHR
Personal Health Record (PHR)	Patient-held record comprising of information provided by a healthcare provider, the patient, a device or a combination of the above
Semantic interoperability	Shared meaning and understanding of clinical data across organisational and geographical boundaries

Shared care record	Enables access to information for providers in primary care or hospitals
Standardised terminology	Defined body of words or expressions used in relation to a particular subject or activity
Summary care record	Continuously extracts and updates key patient information from the local system and stores it centrally (e.g., patient's name, address, age, allergies, current medications and diagnoses)
Super-user	Regular staff member who learns the system prior to implementation so that s/he can expedite IT support and provide problem-solving to other staff
Syntactic interoperability	Consistent methods of importing or exporting clinical information by systems
Usability	Effectiveness, efficiency and satisfaction with which specific users can achieve a specific set of tasks in a particular environment
Vendor	An enterprise selling goods or services
Workflow	Pattern of activity of the end-user

Contents

Executive Summary

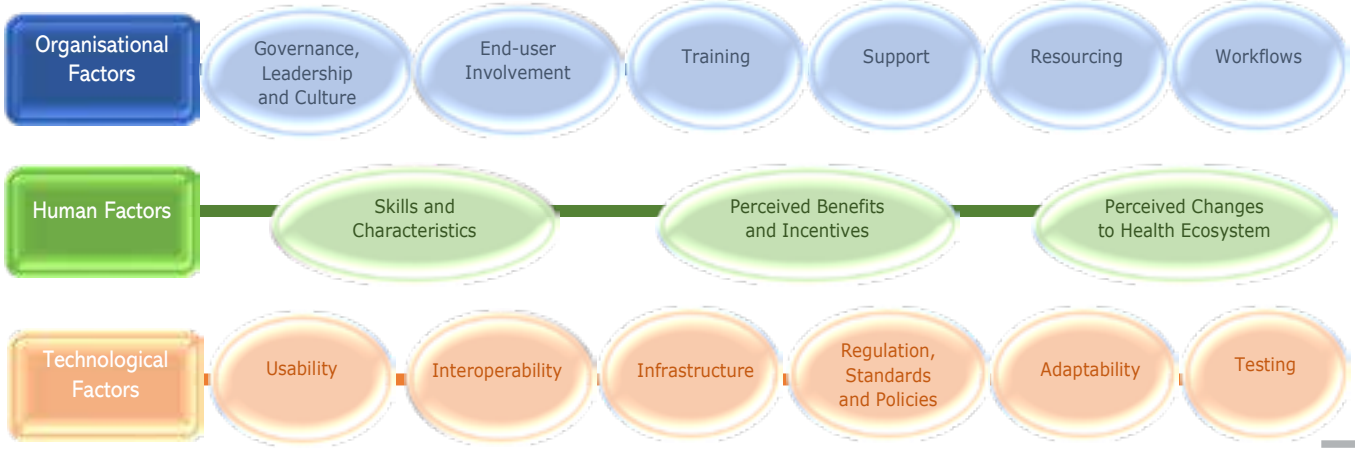
With increasing demands on the health service with a growing and ageing population, information communication technology (ICT) will be critical to ensure a sustainable, quality and safe healthcare service [1, 2]. Information and knowledge are a core asset of health systems and the creation and use of this asset in an effect manner is critical to improve the performance of the system and deliver integrated healthcare [3, 4]. An Electronic Health Record (EHR) provides a longitudinal record of information regarding the health status of an individual in computer processible form, which follows them from one practice or specialist to the next and enables authorised access to patient records in real-time [5, 6]. Implementation of an EHR can bring many benefits to a health service including improved efficiency of healthcare professionals (HCPs) enabling them to spend more time with patients [7] and improved HCP access to patient information in a more timely manner which can reduce duplication in tests and work, and in turn improves patient safety and quality of care [5, 8-14]. Additionally, the EHR expands the capacity to capture and utilise clinical data, enabling the use of clinical decision support (CDS) and retrieval and aggregation of information regarding patients (e.g., conditions or medications) which can be utilised for service development, research and planning service delivery and patient outcomes [12, 15].

However, it is now recognised that to derive true value from an EHR, the implementation process is crucial and can be more important than the off-the-shelf EHR software [16]. Implementation of the EHR not only encompasses the point of Go Live but also the design, development, adoption and ongoing optimisation of the EHR [17]. Even in countries with longstanding EHRs such as the United States (US), United Kingdom (UK) and Denmark, a fully interoperable EHR system across community and acute services has not yet been achieved [13, 18], and many EHR failures have been attributed to the implementation process as opposed to the product supplied by the vendor [19, 20]. Therefore, the focus is no longer on whether or not an EHR should be deployed, but how EHRs should be rolled out and what are the best practices to realise the benefits of the EHR [2].

Although, healthcare contexts vary and several major EHR vendors exist, a high degree of commonality exists across the key critical factors for success [19] and a lot can be learned from the successes and failures of EHR implementations internationally. Therefore, to inform the successful implementation of the EHR in Ireland, a review of the EHR literature was conducted and an Advisory Group was convened. The overall aim of this report was to identify: (i) Key factors for a successful EHR implementation; and (ii) Key considerations for each of these identified success factors.

Key factors for a successful EHR implementation:

Following a literature review and consultation with the Advisory Group, fifteen key factors for a successful EHR implementation were identified and categorised under the headings of Organisational, Human and Technological:



Key Considerations for EHR Implementation from the Literature and Advisory Group

Following a review of the literature surrounding each of the identified success factors for an EHR implementation and based on the valuable experiences and insights of the Advisory Group, a list of key considerations for EHR implementations were identified. These key considerations were reviewed and discussed at several consultative meetings with the Advisory Group. The following key considerations were then endorsed:

Organisational Considerations for EHR implementation:

Governance, Leadership and Culture

1. The patient needs to be at the forefront of all decisions regarding the EHR.
2. EHR implementation is a clinical and cultural transformation rather than an IT project and thus, clinical leaders need to be appointed alongside IT and administrative leaders.
3. Organisational readiness should be assessed at an early stage and then assessed regularly throughout implementation.
4. Ongoing evaluation of the EHR is required to justify the business case, demonstrate success and benefits to end-users, and identify areas within the EHR which should be optimised.
5. Sharing of resources and knowledge between organisations, especially from Live sites, will be important and requires promotion of good communication pathways.
6. New roles will need to be created and where the skills are available, these roles should be appointed in house if possible, but this requires a good governance structure and cohesive strategy for personal and professional development of roles.

End-user Involvement

7. Appropriate champions should be selected from each end-user group to exchange knowledge regarding workflows with IT professionals and foster a proactive IT behaviour amongst their peers.

Training

8. EHR-specific training should be provided by trainers with clinical backgrounds, tiered based on IT skills and workflows, provided to end-users within 8 weeks of Go Live and use different methods (e.g., classroom, drop-in clinics floorwalkers) for various aspects of the EHR.
9. Training requires a significant amount of planning and time which includes the setup of training (e.g., resetting clinical scenarios each day, ensuring domain working) and ongoing training required for new and temporary staff, as well as refresher training for all staff to optimise their use of the EHR.

Support

10. Super-users (i.e., peer expert support) require training as close as possible to Go Live to ensure their readiness to support other end-users, and staff rotas need to be scheduled to ensure super-users are present on every shift.
11. Technical support (both biomedical and ICT) needs to be available 24/7 at time of Go Live, with ongoing support available post Go Live and decisions regarding the supply of this support (i.e., inhouse or outsourced from the vendor or other provider) decided well in advance
12. Ongoing support will be required from other teams managing maintenance, networking and server/platforms for infrastructure issues outside of the EHR software, as well as in case of system going down.

Resourcing

13. Resource planning is important to determine the need for additional staffing at times of training and Go Live, and to backfill those undertaking new roles (e.g., Clinical Champions, Chief Technology Innovation Officer).

Workflows

14. Workflows are the building blocks of the EHR and need to be assessed, mapped and tested early with relevant healthcare/administrative staff, as otherwise scope creep may occur later in the project.
15. Reporting and analytics should also be considered when designing the EHR to ensure the most valuable data is collected, whilst not overloading HCPs and still collecting clinically relevant information to patient care.

Human Considerations for EHR implementation:

Skills and Characteristics

16. IT competence of all end-users should be assessed, and basic IT training should be provided to those requiring it.
17. Staff involved in change management should be supportive, open-to-change and have a positive mindset regarding the EHR.

Perceived Benefits and Incentives

18. Stakeholder involvement is required at every stage of implementation to ensure the EHR meets the needs of end-users and this creates a sense of ownership amongst end-users which increases their acceptance of the EHR.

Perceived Changes to the Healthcare Ecosystem

19. Change management teams, leaders, trainers and support staff should manage end-user expectations and concerns regarding the EHR.

Technological Considerations for EHR Implementation:

Usability

20. End-user satisfaction and efficiency, as well as time required to learn the EHR system will depend on system usability which should be tested and optimised on an ongoing basis.

Interoperability

21. To ensure the EHR can 'talk' effectively with legacy systems within the organisation, interoperability is required, and organisations will not only have to work with the EHR vendor to enable this but also third-party vendors.

Infrastructure

22. Compatibility of all legacy and new software and hardware with the EHR software and the ICT infrastructure of the organisation (i.e., power outlets, Wi-Fi) needs to be assessed prior to Go Live.

Regulation, Standards and Policies

23. Data and technical standards should be set and employed nationally to ensure data quality, privacy and appropriate interoperability.

Adaptability

24. A good relationship with a vendor who is open to sharing data and adapting their product to meet the needs of local organisations and end-users is important.

Testing

25. A comprehensive testing strategy is required and although resource-intensive, it is extremely important to ensure that the EHR workflows work as expected and are safe for patient care.

1 Introduction

1.1. Electronic Health Record: Irish Context

The digital maturity of the health service in Ireland varies between healthcare organisations and paper-based medical charts remain in use in most public acute and community services. However, some progress has been made to embed technology within the Irish health infrastructure [21], including:

- National Integrated Medical Imaging System (NIMIS)
- Lighthouse Projects
- Maternal and Newborn Clinical Management System (MN-CMS)
- Individual Health Identifiers (IHI) Act 2014
- National HealthLink Project
- EPR Project (Project Oak) at St. James' Hospital

Other eHealth projects currently under development in Ireland include:

- National Medical Laboratory Information System (MedLIS)
- Cancer Care eHealth Programme (previously MOCIS)
- ePharmacy Programme
- National Electronic Health Record (EHR) Programme

According to the Sláintecare Implementation Plan Report, the national Electronic Health Record (EHR) is the cornerstone of this eHealth Strategy and it has been identified by the Health Service Executive (HSE) National Directors and Clinical Leaders as the key capability requirement of the future delivery of integrated healthcare [3, 4]. An EHR will provide a longitudinal record of information regarding the health status of a subject of care, in computer processible form, which follows them from one practice or specialist to the next and enables authorised access to patient records in real-time [5, 6]. This differs from an Electronic Patient Record (EPR) (or Electronic Medical Record (EMR)) which provides a longitudinal record of health information within a single institution [5]. As the HSE embarks on delivering the EHR, three national projects have been established (Fig. 1).

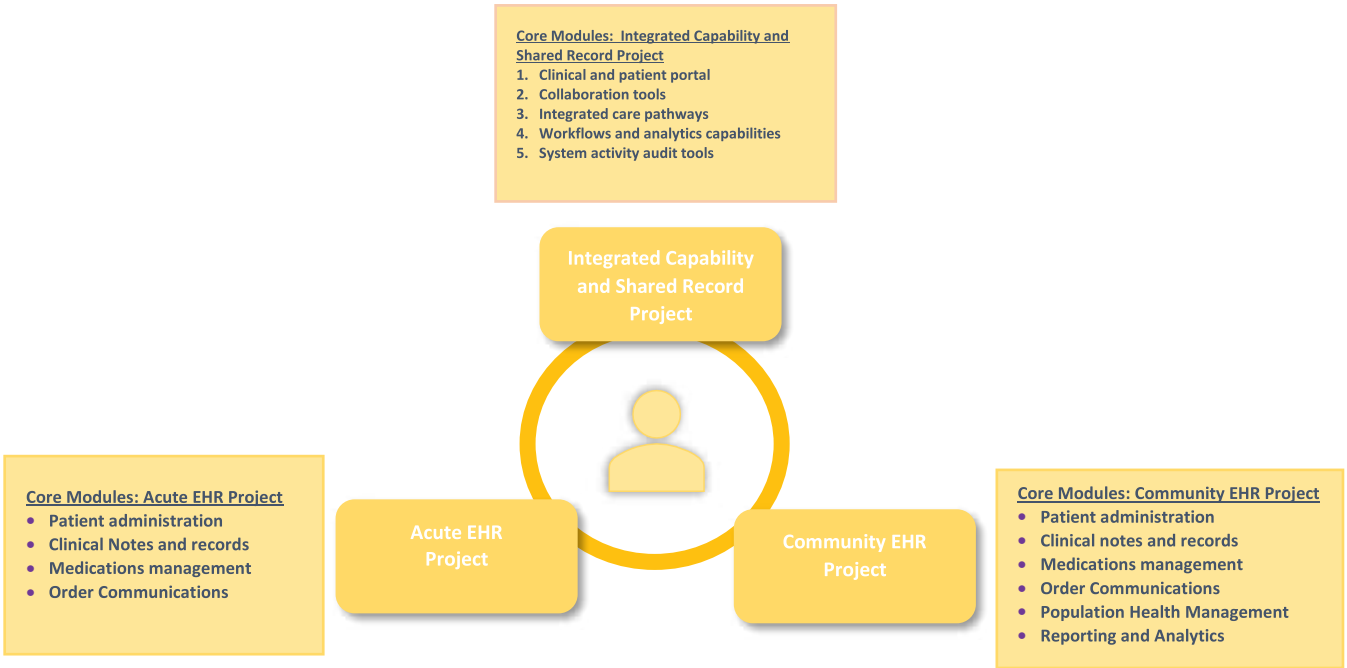


Figure 1. National EHR Programme Projects in Ireland

These projects aim to create a future environment that is information rich, supporting improvements in care, and making a step change in the availability of patient information across the various organisations within the remit of the HSE [22]. Whilst, the acute and community programmes aim to deliver a patient-centred, clinically-driven and integrated EHR to the secondary and primary care services respectively, the Shared Record Programme will aggregate patient data from disparate organisations' IT systems into a single patient centric record. The IHI national register will enable the aggregation of a patient's data to this shared record and improve healthcare professional (HCP) access to patient health records and enhance their capability to coordinate, plan and manage patient care across settings [23]. In the future, making information from the Shared Record appropriately available to patients and carers in the form of a Patient Portal will enable self-care and improved collaboration with patients and carers [23]. These Patient Portals usually comprise of health information documented and managed by the HCP which are important for the patient's care (e.g., medications, appointments) [24]. Personal Health Records (PHRs) have also been utilised and are usually patient-held (as opposed to managed by the healthcare organisation) and comprise of information from the shared record and potentially from information generated by the patient themselves or an integrated device (e.g., wearables) [5, 25, 26].

1.2 Implementation of an Electronic Health Record

1.2.1 Irish Experience

Although perhaps behind other countries in terms of the digital maturity of the health service, Ireland can learn a lot from the challenges and opportunities of recent digital implementations such as the MN-CMS which currently records 40% of all births nationally across Cork University Maternity Hospital (CUMH), University Hospital Kerry (UHK), the Rotunda Maternity Hospital and National Maternity Hospital (Holles Street) [27]. The key findings from this national implementation have been collected and analysed using the framework of key success factors identified in this report and are presented in Appendix A.

1.2.2 International Experience

Whilst healthcare contexts vary and several major EHR suppliers exist, similar challenges and facilitators have been discussed across different countries [19]. One of the most important learnings is that the process of implementation of an EHR is as, if not more important than the system itself [16]. In this report, the implementation process refers to the several stages of implementation including: procurement, design, development, adoption and optimisation [17]. Despite the widespread implementation of many successful EHR systems (e.g., Denmark, US, UK, Sweden), no country has achieved a fully interoperable EHR system across community and acute services [13, 18]. For example, in the United Kingdom (UK), the National Programme for Information Technology (NPfIT) was formed in 2002 and it was the largest public sector IT programme ever attempted in the UK [19, 20]. However, after a history marked by delays and implementation issues, it was dismantled in 2011 and the entire EHR implementation process was restructured [20]. In the United States (US), EMRs have emerged since the 1970's but it was only when the Health Information Technology for Economic and Clinical Health (HITECH) Act was enacted in 2009, that adoption rapidly increased [28]. Between 2011 and 2018, the US government has paid hospitals and physician offices $38 billion in EHR implementation incentives [29], however despite widespread adoption, procurement and implementation of EHRs at individual healthcare organisations has made it very difficult to share data with outside healthcare organisations [30]. Therefore, a combination of organisational, cultural, human, technical and data governance issues have underpinned the difficulties in developing a fully interoperable EHR internationally.

2 Literature Review and Expert Consultation

2.1. Aims

An initial scoping review of the literature identified several literature reviews relating to EHR implementation. Comparing and contrasting findings from existing literature reviews enables synthesis of the highest level of evidence available [31]. Therefore, a review of the available literature reviews was conducted with the aim of identifying, exploring and synthesising the existing literature on the key factors for a successful EHR implementation. The overall aim of the report was to provide an overview of the key factors for a successful EHR implementation based on the findings from the literature and the valuable experiences of the Advisory Group.

2.2 Methods

2.2.1 Search Strategy

A large number of search terms to describe *"Electronic Health Record", "Implementation"* and *"Literature Reviews"* were identified from previous systematic reviews [12, 32-36], additional literature [37], medical subject heading (MeSH) or controlled vocabulary from selected reference search engines, and via consultation with experienced information technologists, researchers, clinicians and a liaison librarian at the Health Sciences Library, UCD [Appendix B]. The three categories of search terms were combined using Boolean Operators and the search was employed across nine databases: PubMed, CINAHL, Scopus, Embase, Web of Science, IEEE Xplore, ACM Digital Library, ProQuest and Cochrane. Grey literature (i.e., materials not formally published by peer-reviewed journals), such as reports and conference proceedings, were also searched including: international Health Informatics Societies; the World Health Organisation (WHO); European e-health network; Kings Fund, Gartner; ProQuest thesis and dissertations; and Lenus. Following data analysis, further searches of the literature were conducted which combined the search terms related to *"Electronic Health Record*" with each of the identified factors (e.g., Training).

2.2.2 Identification of Studies and Data Extraction

Titles and abstracts of studies identified from the search were screened. Inclusion criteria included literature reviews identifying factors which influenced the successful implementation of an EHR and published in the English language within the last 10 years. Twenty-five literature reviews were identified and a standardised proforma for data extraction was developed.

2.2.3 Data Analysis

The factors extracted from the included literature reviews underwent a qualitative content analysis [38]. Using an iterative process, a list of codes was formed and each of the identified factors was categorised under a code, with additional codes created where required. These factors were then categorised using the framework which is used across the HIT literature: Organisational, Human and Technological [9].

2.2.4 Advisory Group Consultation

Each of the factors related to a successful EHR implementation from the literature were reviewed by the 10 members of the Advisory Group who had experience and insights into implementing large scale IT projects. Using an adapted nominal group technique, the advisory group came to a consensus regarding the factors for EHR success as well as the key considerations for a successful EHR implementation during several consultative meetings.

3 Organisational Factors

Implementation of an EHR system is more than just software delivery and adoption, it requires organisational change, and sociotechnical and contextual domains are a primary challenge [9]. Organisational factors relate to the processes by which the EHR is introduced and incorporated into routine care by professionals and/or patients within the healthcare organisation [39]. This includes everything that needs to be in place prior to and during the implementation of the EHR [9]. The following organisational factors were deemed important for a successful EHR implementation in the literature and by Advisory Group:

3.1. Governance, Leadership and Culture

Good leadership at the local and governance levels have been shown to be critical for the successful implementation of an EHR system [12, 32, 40, 41] and for creating a favourable organisational culture for EHR adoption [42, 43]. Without good leadership, EHR implementations have failed [9] and therefore, it is important to appoint the right person to each leadership position, whether that is at the level of governance (e.g., Chief Information Officer), project management (e.g., Team Lead) or end-users (e.g., Clinical Manager). According to the literature, leaders should possess good communication skills [42], have a positive attitude towards the EHR, be willing and able to devote sufficient time to the project [44], be able to balance risk and reward in deploying resources for EHR implementation [45], and engage frontline staff [41]. Barriers to good leadership have included poor relationships and communication between leaders and frontline staff, and conflicting goals at different levels of management [9, 45]. Some leaders may already be in these roles prior to the EHR implementation, however, any pre-existing underlying issues between them and end-users needs to be highlighted and alleviated prior to beginning the EHR implementation process [9, 45]. These leaders should also be made aware that with the nature of an EHR implementation, they will need to be able to work with end-users on a participatory level during the initial stages (i.e., design and development) and then this will change to a more hierarchical leadership strategy at the later stages [32, 46]. Leadership at the governance, project management and local levels, as well as the organisational culture are discussed in further detail below.

3.1.1 Governance Structure

Key aspects of the governance structure discussed in the literature were the: (i) Governance approach to EHR implementation; (ii) Governance roles in EHR implementation; and (iii) Organisation-vendor relationships.

(i) Governance Approach to EHR Implementation

Three approaches to the governance of EHR implementation have been discussed in the literature: the government-driven top-down, the locally-driven bottom-up and the middle-out approaches (Table 1). Perhaps due to the private nature of the healthcare system in the US, a bottom-up approach was

deemed most appropriate. However, lack of national regulation contributed to procured systems not consistently generate the quality and productivity benefits foreseen such as health information exchange across organisations [41, 43, 47]. Whilst a top-down approach in the UK should have enabled such benefits with the standardisation of processes and systems, lack of local involvement and engagement resulted in the UK changing their approach to a regionally-led project which is connected to a national spine (i.e., middle-out) [48]. Therefore, an appropriate balance between national co-ordination and local management has been recommended [19]. This would see development of national policies and standards to facilitate standardisation [5, 41, 49, 50], leaders with a clinical background promoting engagement and support of end-users [32, 51], and a political engagement and willingness at the national level [52]. In France, the loss of engagement by politicians during the chaotic first months after Go Live of a national PHR was reported as a contributing factor to the initial failure [53].

Table 1. Comparison of the Top-down, Middle-out and Bottom-up approaches to EHR governance

	Top-down	Middle-out	Bottom-up
Definition	A government-driven and centralised approach [16]	Governments create a common set of goals and underpinning standards but local organisation manages the project [16, 48, 54]	Each local organisation freely sources own product
International examples	UK*, Netherlands, Austria [16]	Denmark, Canada, New Zealand, UK* [16]	US, Norway, Sweden [48]
Benefits	• Promotes more efficient procurement [48] • Promotes better compliance with standards [48] • Facilitates health information exchange [48]	• Brings together the common needs of clinicians, IT industry and government [48] • Helps to develop more cost-effective, flexible, higher quality system[48] • Capable of information sharing [48]	• Meets local needs [48]
Challenges	• Systems not meeting local needs [48, 55] • Little capacity to adapt quickly to changing health service needs [48, 55] • Local leaders being disengaged [48, 55] • Difficulty demonstrating success[48, 55] • Poor engagement and support of end-users [56]	• Requires national standards and governance structures • Duplication in effort across organisations [45] • Need discussions between organisations to reach agreements [45]	• Health information exchange is more challenging [16, 47, 48] • Inconsistent data models [16, 47, 48] • More effort required for system procurement [16, 47, 48]

The UK started with a top-down approach but their future direction is a middle-out approach.

(ii) Governance Roles in EHR Implementation

With the development of computerised information systems came the recognition of the need for a governance structure of informaticians who can design, implement and leverage these systems [57]. This has led to the development of a number of roles:

Chief Information Officer (CIO): The role of the CIO is to help set and lead the technology strategy for an organisation in concert with the other C-level executives. The CIO is tasked with providing an executive-level interface between the technology department and the rest of the business as well as driving change and transformation within their organisation. Although traditionally a non-clinical professional, this may not always be the case [57, 58].

Chief Clinical Information Officer (CCIO): Recognition of the importance of clinical experience in understanding how best to design, implement and benefit from ICT in a healthcare setting, led to the

development of the CCIO. The CCIO bridges the gap between clinical care and technology for large sectors of healthcare workers, provide a clinical focus to ICT projects and understanding of the impact of health information technology on care processes, as well as act as clinical leaders [57, 59]. CCIOs may originate from different disciplines and where more than one CCIO is appointed, their titles may be specific to their background including the Chief Medical Informatics Officer (CMIO), Chief Nursing Informatics Officer (CNIO) and the more seldom used Chief Pharmacy Informatics Officer (CPIO) [57]. A person being appointed as CCIO should have a background in clinical care, health informatics and leadership, however, these characteristics are reportedly difficult to find [57, 59]. Therefore, the American Medical Informatics Association (AMIA) [57] and the UK Wachter [59] and Topol [60] Reports have all recommended the development of digital leadership and health informatics educational programmes, not only to train future CCIOs but to prepare the healthcare workforce for the future digitised healthcare ecosystem. Some organisations in the USA reportedly have multiple CCIOs for several clinical informatic disciplines, but this need will vary depending on the size of the organisation and availability of the required skills [57]. The UK Wachter report recommended the appointment of a CCIO for each trust who is supported by other clinical informaticians as well as a national CCIO with organisational and budgetary authority, to perform a crucial co-ordinating function [59].

More recently, the increased focus on optimising an EHR to support research data acquisition and reporting and analytics has led to the development of further roles:

Chief Research Information Officer (CRIO): The CRIO is usually an established academic with experience in health informatics and research [58]. The CRIO may only be required in organisations which conduct substantive research such as University Hospitals as their role is to assist in the design and optimisation of an EHR to support research data acquisition, embed research into clinical practice and ensure research data governance and compliance [58].

Chief Data Officer (CDO): The CDO may be responsible for determining what types of information the organisation wishes to capture, retain and utilise, and what purposes.

Chief Analyst Officer (CAO): The CAO may be responsible for data analytics and reporting.

(iii) Vendor-Organisation Relationship

The CIO along with the CCIO may be responsible for collaborating with vendors and building a trusting relationship with them, which works for both parties [22, 45]. Barriers to good partnerships between the healthcare organisation and the vendor have included vendors proposing unrealistic timelines and limited opportunities to adapt the EHR technology [61]. However, having a vendor set hard deadlines for the organisation was also discussed as a positive on reflection by a UK hospital, as it helped them to deliver the EHR on time [45]. To build a strong relationship between the organisation and vendor there needs to be sufficient dialogue and a shared vision of success [22, 45, 61], and the vendor must be open to sharing data and adapting the product [11, 32, 45]. It is also recommended that the vendor has proven their ability to produce successful products, and can identify workflows and adapt their product accordingly [11, 32, 45]. Decisions regarding the level of support and training provided by the vendor should be confirmed at procurement stage [62].

The selection of a vendor is shown to be very important and in the US, vendors have largely controlled the exchange of health information between organisations [63]. Where a single EHR vendor is used, higher levels of health information exchange have been demonstrated in the US [30]. Use of a single vendor can also help reduce transaction costs as a single contract is required and other advantages include faster design and deployment of highly configured and integrated end-to-end products, centralised software updates and focus on a single project [64]. However, no one vendor could meet all

the ICT requirements of a healthcare organisation covering functions from medical imaging to patient administration [5]. Additionally a single vendor risks vendor lock-in where healthcare organisations need to reengineer their business policies and operating procedures to accommodate the vendor design, making it difficult to change vendor if required later in project [45, 64]. Vendor lock-in can also occur when implementing new network solutions into an existing environment or when future upgrades are needed.

Other countries such as the UK and Denmark have procured EHR products from several vendors [20, 65]. A best-of-breed strategy enables healthcare organisations to procure systems closely aligned to their requirements, helps to retain the competitive advantage between vendors, allows specific functions to be upgraded or replaced individually, and is less risky should one aspect fail [64, 66]. However, this strategy can result in functional and data silos [64, 66]. The best-of-suite is a hybrid approach of the single vendor and best-of-breed strategies, which sees healthcare organisations use a package of applications as the basis for integrating all other applications, but this is more complex [64, 66]. Additionally, the vendor's experience of EHR implementation within the same healthcare context can impact on the implementation, for example, deployment of the EPR in Cambridge in the UK, was the first outside of the US for this vendor and this had a major impact on the work involved in meeting the workflows of HCPs [67]. Although best-of-breed and best-of-suite approaches both come with advantages and disadvantages, its most important that the right solution is chosen for the specific environment.

3.1.2 EHR Project Management

Project management is a critical factor for a successful IT project implementation [42]. A project management or implementation team has usually been appointed to manage the EHR implementation process and they will also be crucial to evaluating the project and developing the implementation approach. Therefore, a summary of the literature is presented below related to the: (i) Project Management Team; (ii) Project evaluation and Benefits Analysis; and (iii) EHR Implementation Approach.

(i) Project Management Team

The number of members within the project management or implementation team will depend on the size and type of facility, the team may consist of three or more members from a cross-section of backgrounds (i.e., IT, administration and clinical) and departments, and should include representatives from front-line staff with one person designated to make final decisions [43, 44, 68, 69]. These members may include: EHR Team Lead; EHR Implementation Manager; Information Technology Lead; Workflow Redesign Lead; Clinical and Administrative Leads (i.e., representatives of end-users); and a Super-user Lead (i.e., management of the designation of support staff) [44]. A project manager is usually appointed but not always. A case study at an English hospital discussed a reportedly successful implementation where tasks were shared amongst the team members rather than having a project manager, as the EHR is not a once-off project [70]. Although the vendor may provide development and implementation plans, the EHR project team will need to align these with local context and organisational routines [12]. The project management team should be responsible for some or all of the following [41, 71]:

- Project planning
- Developing realistic timelines and tracking milestones
- Business plan and cost estimations
- Delineation of roles and responsibilities
- Communication of strategy with staff

- Tests organisational readiness, and develop incentives and innovation structures for change management
- Identify policy and process changes required
- Quality control

(ii) Project Evaluation and Benefits Analysis

A benefits-driven EHR approach to implementation and optimisation is recommended to drive substantial improvements in clinical quality, patient safety and/or operational and clinical efficiency. Previously, success was often measured by the use or non-use of the technology, however, to gain the value of an EHR, true success factors need to be identified [9]. The Healthcare Information Management Systems Society (HIMSS) have proposed the following measures to evaluate the success of a project: being on schedule; within scope; within budget; satisfied team; patients benefits; and achieving project quality [72]. The goals of the EHR implementation should also align with the EHR strategy, key performance indicators of the organisation, organisational culture, management style, and typical evaluations of project achievements [71, 73]. However, the complexity of an EHR means that various stakeholders can interpret success differently [9] and where goals have been set centrally, there have been mismatches in relation to what was needed and feasible locally [48]. Therefore, there needs to be agreement amongst key stakeholders including hospital/system executives, clinical leaders and department leaders regarding the project objectives and they need to share this clear vision of success amongst their leaders, vendors and end-users [71, 73]. Additionally, appropriate sponsors should be appointed for the critical success factors which may be the CIO, CCIO or hospital CEO, and they should be focused on achieving the benefits over at least a one- to two-year timeframe post go-live. Each of the objectives should be measurable and evaluation of these objectives should occur on an ongoing basis post Go Live [2]. A continuous process of monitoring and evaluation should be created to optimise the EHR and its benefits [19] and this helps create a culture of continuous quality improvement amongst staff [73].

(iii) EHR Implementation Approach

The EHR project management team also need to plan for either a 'Big Bang' or 'Phased' EHR implementation (Table 2). Phased implementation of an EHR, also known as incremental or staggered implementation may occur in various ways for example, by hospital ward, class of data or function (e.g., prescriptions), locality (e.g., hospital group), type of care setting (e.g., acute hospitals), condition (e.g., Epilepsy lighthouse project) or sub-population (e.g., maternity and newborn) [22]. Whilst, phased implementation has been recommended for large organisations with complex processes [34], the risks for patients of using a hybrid of paper and electronic charting need to be considered and mitigated by analysing the entire workflow end-to-end and putting strict processes in place [74]. For example, phased implementations often don't begin in the emergency department as this would result in the transfer of many patient records from a an EHR ward to a paper-based ward [45, 74].

At a national level, there are also advantages of phasing implementation in larger organisations compared to smaller organisations and vice versa, with larger healthcare organisations facilitating testing of most specialities and interdependencies, as well as training of a large amount of staff to use systems which may benefit future implementations, whilst smaller hospitals facilitate testing of critical workflows and integrations in a live environment to identify urgent issues with minimal consequences as fewer patients and clinicians are involved in using systems [65]. Additionally, some countries such as Denmark chose to phase implementation in primary care first with medication prescriptions linked to pharmacies [65]. The most appropriate implementation approach for an individual organisation should be made based on the individual requirements, resources and change readiness of the stakeholders and organisation [75].

Table 2. Advantages and disadvantages of the 'Big Bang' versus 'Phased' EHR implementation approaches		
	Big bang	**Phased**
Definition	EHR turned on across organisation in one Go Live (i.e., over a day or week) [74, 76, 77]	Staggered implementation with successive Go Lives [74, 77]
Advantages	• Mitigates risk of two parallel systems [65, 74, 76] • Less interface support needed [77] • No need for interim workflows while awaiting next function to Go Live [74, 77] • Less opportunity for scope creep [77] • Greater initial impact on productivity [76] • Less change fatigue [74] • Continuity of care for patients [74]	• Less strenuous on staff [76] • Resourcing requirements can be spread out over longer time [77] • Can reduce cost [78] • Less support needed at Go Live [74, 77] • More manageable [71, 77] • Less intensive and quicker training [77] • Learnings after each Go Live [45, 74] • Incremental gains builds support amongst end-users [71]
Disadvantages	• High financial costs at one time [76, 77] • High staffing, support and training requirements [74, 76, 77] • Higher potential of catastrophe [76] • Requires significant testing [74] • A lot of change for end-users at one time which could decrease acceptance [74, 76, 77] • Requires a reduction in workload/patient throughput at time of Go Live [76]	• Greater risk of scope creep [76] • Safety risk of confusion using two systems [45, 65, 74, 76] • Potential duplication in work if using two systems [74, 77] • May require expensive interfaces between systems [77] • Change fatigue amongst end-users over time [45, 74, 76, 77] • Prolonged time to realise significant benefits [76] • Fractured paper/electronic workflow [74]

The selected implementation approach as well as clinical setting will impact on the resources required for data migration from the paper medical charts to the EHR [79], as well as the process selected. For example, ensuring all information is accessible during a 'Big Bang' implementation across all wards in a hospital will be more challenging than in a smaller organisation, and having co-existing paper and computerised records is reportedly difficult [12]. Therefore, some EHR implementations have discussed scanning all legacy medical charts into the EHR which enables the healthcare organisation to go fully paperless and ensure 'one patient, one record', however, this is a time-consuming and expensive process [75, 80]. Another option is to scan-on-demand as patients present [80] and whilst this would be initially less costly, it requires retention and storage of paper medical charts, ongoing data migration and continued searching for paper charts [81]. Additionally, navigation of scanned documents within the EHR is difficult as they are only searchable through manual scrolling unless individually indexed (another time consuming task) and they do not facilitate use of alerts, clinical decision support (CDS) and auto-fill [82]. A third option for data migration is to transfer a minimal core clincial data set from the paper chart into the EHR. The minimal data set would vary depending on context and require clinical input in these decisions is imperative. Addiitonally staff must be aware that prior to a certain date, only minimal data is available electronically and processes for accessing paper charts would still need to be available [75]. Whilst the workload involved in data migration will vary depending on the EHR implementation approach and the data migration method chosen, a data migration team will be required and may consist of a Data Migration Manager, Data Migration/Entry Group, Data Quality Assurance Lead and Interface expert [69]. This team must be familiar with the new and legacy systems and include HCPs, and will require access to appropriate infrastructure such as computers, WiFi and space.

3.1.3 Local Leaders

Local leaders are also critical to a successful EHR implementation as they engage and support the end-users and communicate with the project management team and IT staff [12, 18, 41, 49, 83]. Whilst some of these leaders may already be in place prior to the EHR implementation such as managers, professional networks and policy-makers, local champions should be appointed. It is extremely important that

clinical managers are engaged in the EHR and understand their role as a leader during the EHR implementation as they will be allocating time to their staff for training [84] as well as reducing clinical workloads of end-users operating in support roles (e.g., superusers) and in EHR design roles (e.g., champions). Their support to end-users will be of utmost importance as they are usually respected and have ample opportunity to engage and support end-users by using the EHR themselves, demonstrating the benefits, being visible during Go Live and helping trouble-shoot with their staff [12, 85]. Managers will also need to identify the needs of their staff (e.g., basic computer literacy training; number of super-users required) [84] and appoint appropriate super-users and champions and support staff undertaking these roles in addition to their clinical workload [86].

Local champions act as ambassadors for their peers and operate in a liaison role by communicating clinical and administrative priorities with the implementation and IT teams, as well as realistic expectations with their peers [61, 76]. It has been suggested that not having local champions is one of the biggest risks to EHR success [9]. Traditionally in EHR implementations, champions were always physicians, however, it has now been recognised that a champion should be selected from each stakeholder group (i.e., nursing, allied health professionals, pharmacy, administration etc.) to lessen medical dominance and engage all staff members [32, 34]. Whilst their role as advisor to the IT staff will be discussed in further detail under *Section 3.2 End-user Involvement*, performing this role fosters a sense of ownership amongst all end-users they represent and helps improve buy-in [9, 13, 32, 41, 45, 51].

3.1.4 Organisational Culture

Organisational culture is very important for a successful EHR implementation [9, 12, 49, 52] and is a major factor affecting the speed and frequency of innovation [60]. A favourable culture should be open, supportive and ready for digital change, it helps to foster good relationships between end-users and leaders [9, 12, 49, 52]. This favourable culture is promoted when the organisation has prior experience of a digital change, however not all organisations will have this experience [9, 12, 49, 52]. Therefore, other ways to create a favourable culture for successful EHR implementation include:

- Good leadership and management including clinical leaders [42, 43].
- Senior leadership demonstrating the priority of the implementation with provision of resources (e.g., purchase of infrastructure, allocation of new roles) [9, 32, 74, 87].
- Communicating clear and consistent visions of the project with all end-users [12, 32, 71, 88].
- Rewarding change with timely feedback [9, 12, 32, 74, 87].
- Demonstration of success and positive benefits either from other sites and current site [88].
- Promotion of a favourable environment for teamwork and sharing learnings, information and resources between organisations at different tiers of the health service [9, 18, 45, 59].
- Provide individual organisations with opportunities to manage their project and 'make it their own' [88].

Key Findings for Governance, Leadership and Culture:

1. EHR implementation is a clinical and cultural transformation as opposed to an IT project and thus, clinical leaders are required to create an organisation which is open and supportive of change.
2. Leaders at the governance, project management and local level need to engage and support end-users as well as develop a trusting relationship with the vendor.
3. Appropriate approaches and processes to EHR implementation will vary depending on the context but some national guidance and inter-organisational communication is recommended.
4. To ensure benefits-realisation of the EHR, clear and measurable objectives which align with the EHR strategy need to be identified amongst stakeholders and reviewed on an ongoing basis.
5. Champions should be identified from each stakeholder group to act as role-models to peers.

3.2 End-user Involvement

Implementation of an EHR system is primarily a clinical transformation project rather than an IT project. Therefore, involvement of end-users from all stakeholder groups at all stages of implementation has been identified as critical to ensure the EHR meets the needs and workflows of the end-users [9, 32, 33, 43, 83]. People need to be prioritised during development as achieving successful adoption of an EHR system is largely influenced by the end-users of the systems [9, 60] and a user-centred design has been promoted in the literature [59]. Where end-user involvement has been lacking, it has been deemed a barrier to successful implementation [8, 9, 12], with UK [45, 55] and French [53] studies listing it as a contributing factor to failures in national EHR implementation processes. Involving end-users from the procurement phase onwards reportedly:

- Promotes user ownership over the EHR as it gives them an opportunity to influence and shape the technology [32, 45].
- Increases collaboration amongst IT staff, HCPs and administrative staff [61, 76].
- Increases EHR acceptance amongst end-users [9, 32, 43].
- Ensures configuration of an easy-to-use product that has a positive impact on workflows [32, 43, 71, 89].
- Avoids unnecessary resources being spent on developing EHR functions which won't be used [12].
- Facilitates the early identification of problems resulting in faster development of the EHR and fewer adaptations required in the future [32, 43, 89].
- Provides insights into the needs and concerns of all end-users [45].
- Ensures the right data is collected to monitor performance [45].

Usability testing and process requirements are now considered a mandatory element of a user-centred design by the Office of the National Coordinator of Health Information Technology EHR Certification Program criteria [90]. During design and development, HCPs will be able to describe the workflows and test the prototypes in a more beneficial way than those with an IT background [9, 41, 45]. Therefore, vendors need to obtain user involvement at this stage [41, 45]. Finally, identifying the most suitable data entry devices (e.g., mobile versus stationary) and the need for support and training should also involve end-users [12, 60]. Every opportunity should be given to users to provide ongoing feedback during and post implementation and organisations need to listen to concerns and make the necessary changes to the technology [45]. Methods for obtaining this feedback may include testing prior to implementation [33] or pathways for reporting issues to IT service management/operation teams via managers or super-users. Challenges which have existed in relation to this include inflexible products, under investment in technical staff to adapt the product, difficult relationships between leaders and users [45], and time constraints which limit consensus building [33].

Local champions act as the translator or 'bridge' professional between IT and front-line staff, and ensure the ultimate goals of the project (i.e., patient-centred care) stay in focus [61, 76, 91]. A diversity of stakeholders are usually recruited as champions including clinical staff, administration, researchers, audit and quality improvement teams, policy-makers and management [32, 33, 45, 52]. Champions should be well-respected, recognised and liked individuals, with the adequate IT knowledge, training and experience to be able to customise and exchange knowledge regarding workflows with IT professionals and foster a proactive IT behaviour amongst colleagues [92]. To play a meaningful role in the development and change process of the organisation, they need to have an understanding of what

is possible from a digital system (e.g., data sharing between organisations requires interoperability) [45].

Early involvement and engagement of champions in the process from procurement to implementation is required [41], otherwise the risk of poorer outcomes exist, as occurred in the UK with their top-down management approach [55]. Having a local champion reportedly helps foster a sense of ownership, acceptance, enjoyment, confidence, self-pride, increased buy-in and improved adoption amongst all frontline staff [9, 13, 32, 41, 45, 51]. It has also been suggested that not having champions is one of the biggest risks to EHR success [9]. Traditionally, patients have not been included in the development of such large scale, complex, national EHR systems but it has now been recognised that patients and their carers provide an unique insight on the characteristics of information flow across the entire system and ensure the EHR is patient-centric [7, 12, 45, 60, 93]. The failure of the patient portal in England is one example of where a national project was abandoned due to lack of patient participation in design and thus, it didn't meet the patients' information needs [91].

However, being a champion will require time out of clinical or administrative roles and could constitute 10-50% of their working time depending on their responsibilities in relation to design and participating in collaborative peer networks [45, 60, 94]. Champions are also important in smaller hospitals and primary care settings [13], however, smaller workforces may limit the availability of the required IT capabilities, and sharing of external knowledge and staff between organisations should be considered to ensure local champions are in place [9]. In conclusion, managers need to involve and provide training and support to suitable EHR champions who can promote positive attitudes towards the EHR system amongst their colleagues and negotiate the needs of frontline staff with the IT professionals and management.

Key Findings for End-user Involvement:

1. End-user involvement is of utmost importance to ensure an EHR as it is a clinical transformation rather than an IT project.
2. Gaining end-user involvement throughout each phase of implementation helps ensure the EHR meets the needs of end-users and promotes a sense of ownership and increased acceptance amongst the end-users.
3. HCPs will need time away from their clinical work to be involved as champions in EHR design, development and testing.

3.3 Training

Training end-users is a critical component of an EHR implementation [11-13, 18, 32, 33, 43, 50, 51, 95] and lack of EHR training or inefficient training is deemed a barrier to a successful implementation [11, 13, 47, 96]. Providing good quality training to end-users has been shown to improve their proficiency, accuracy, time management, satisfaction [12], engagement and acceptance [18, 34, 41, 85], and reduces overall disruptions to end-user workflows [41]. On the other hand, poor or insufficient training can hamper progress, result in failure to meet the full potential of an EHR, and foster insecurities and concerns amongst end-users [8, 12]. Additionally, poor EHR usability requires greater training time for end-users [73], whilst a flexible, usable and intuitive system will facilitate ease of learning and reduce the burden of training *(See Section 5.1 Usability)* [18, 97].

Whilst the key considerations for provision of effective training will be discussed in further detail (Fig. 2), other important considerations for training include ensuring all end-users, irrespective of IT experience, attend training and have adequate time to learn in addition to their large clinical workloads [11, 12, 33, 41, 49]. This requires engagement of management to ensure adequate planning of staff rotas training time is allocated [84] and planned for all staff [11, 12, 33, 41]. Additional incentives may need to be provided to staff to ensure full attendance at training which in the past have included organisations offering continual professional development credits and provision of EHR security access at time of training sessions [94].

Figure 2. Key considerations in the provision of effective EHR training

Training Methods

Decisions regarding provision of training are highly specific to the institution, user skills and availability of resources. Methods of training discussed in the literature include: class-room based using task simulation [11, 98]; one-to-one via shadowing or supervision during clinical tasks [11, 33]; e-learning modules or paper-based manuals [95]; 'mass' training sessions; or a combination of the above [69, 94]. As it is more cost-efficient, classroom-based training has been commonly utilised to educate end-users on the more complex EHR functions and workflows as it facilitates individualised assistance, assessment of competency and maintains trainer-student interaction [60, 69, 94]. However, class-room based learning requires co-ordination of the HCPs' rotas to enable participation in group sessions, as well as a large physical space for learning with a computer for every participant [60, 69]. End-user involvement should be obtained in selecting appropriate training methods [60], with some HCPs reportedly preferring 'learning-while-doing' compared to class-room-based [11, 69]. However, user preference may not always be feasible as one-to-one training is costly [33]. E-learning was identified as being helpful for basic review of the structure and function of the EHR and it reduces the time commitments of end-users compared to class-room based-learning [60, 69, 94]. It also has potential to mature from a generic 'one-size-fits-all' model to a personalised and adaptive experience through data analysis of learners, their actions and their context using artificial intelligence (AI) [60]. However, it lacks individualised assistance and can conjure up negative ideas of statutory and mandatory training [60]. Therefore, a blended learning

approach of classroom, e-learning and one-to-one has also been recommended [60, 69, 94]. Manuals have also been provided by the vendor for training purposes but these are often generic in nature compared to those developed by end-users in the specific site organisation [99]. Outside of the formal training, end-users need time to learn and become familiar with the system, thus, playground modules [41, 84] and drop-in labs [94] have enabled users to gain more practice using the system, set preferences, learn more about mobile device and remote access, and to ask questions .

Training Providers

Training teams have been developed in some organisations to plan and provide training to end-users. Members of training teams may include a training lead, trainers, floorwalkers and e-learning developers [69]. Trainers have often been provided inhouse or from another healthcare organisation [84, 94], the vendor or a consultancy firm [11]. According to the literature, whilst vendors often provide training prior to implementation, these trainers often lack an understanding of clinical workflows of the specific organisation [62, 84, 98], vendors may not have capacity to provide sufficient numbers of trainers [62] and they usually only provide training sessions prior to Go Live [11, 49, 51, 100, 101]. Whilst these trainers or IT staff may be utilised to train end-users, it has been recommended that where possible, peers were used to train end-users alongside the trainers, as they can articulate solutions to end-users in a way they understand [32, 33, 85, 98]. As well as having the clinical understanding and relationship with training participants, inhouse trainers provide the added benefit of retaining the knowledge learned during training within the organisation. Trainers should also be patient with the end-users and be able to adapt to the varying degrees of users' knowledge and computer skills [33, 62, 94]. To ensure sufficient trainers, studies have recommended a ratio of trainers to end-users of 1:6 and reported the presence of 10 (range 6-18) end-users per classroom-based training session [69, 84, 94].

Training Content

EHR training content should be tiered based on end-users' capabilities [33, 41, 85, 101], with provision of basic computer literacy training to those with lower levels prior to EHR training *(See Section 4.1 Skills and Characteristics)* [32, 52]. Grouping of end-users with common workflows and tailoring of training to the specific EHR needs of different disciplines has also been recommended [33, 51, 94, 101], which allows trainers to focus on the critical tasks of those specific users' daily workflows [33, 34, 62, 98] and maintain user engagement in training (e.g., operating staff may not need to focus on admissions and discharging patients) [94]. Tiering and tailoring of training will subsequently reduce time commitments of staff and improve engagement in training which is critical [50, 102]. To provide comprehensive training, all parts of the EHR should be ready at time of training [100], and there needs to be temporary user logins [84] and clinical scenarios [33, 84]. This requires a significant amount of preparation time for trainers as clinical scenarios need to be reset, the domain needs to be working and the room needs to be set-up prior to each training session. In addition to navigation of the EHR, studies have discussed the need to include education of how functions were generated to build end-user trust in them (e.g., alerts) [103] and formal training on communicating with patients whilst concurrently using the EHR [104, 105]. Trainers should also use the training sessions to address any end-user concerns [60] and inform them of the benefits of mastering the EHR [49].

Timing of Training

It has been recommended that training is provided as close to Go Live as possible (i.e., no sooner than 8 weeks prior to Go Live) to ensure end-users remember it [94, 106] and to ensure end-users are trained using the final system which will be deployed [32, 85]. To facilitate training during this period, lighter workloads, compensation for longer working days and staff back-fill may be required [11, 33, 49, 50]. Trainers and support staff (i.e., super-users) will require extra training to enable them to provide frontline support to other end-users [84, 86, 98]. Where Go Live has been postponed, this resulted in long

delays after training and costly refresher courses and thus, should Go Live be postponed, training should also be delayed [33, 94].

Ongoing and refresher training:

In addition to initial training at time of implementation, ongoing training opportunities are essential to retrain users, optimise EHR use and orientate new and temporary staff [11-13, 33, 34, 50, 51, 101]. Although the literature has recommended training super-users prior to end-users, this may necessitate refresher training prior to Go Live [84, 106]. To address any ongoing training needs end-user skills should be assessed prior to Go Live [84, 94]. Manuals have reportedly been more useful for ongoing training or use of the less common functionalities [99]. However, inhouse trainers are recommended for ongoing training for new staff as vendors usually provide a once-off training only and were reportedly slow to respond to ongoing training needs and orientation of new staff [11, 49, 51, 100, 101].

Key Findings for Training:

1. Basic computer literacy training should be provided to those requiring it prior to EHR-specific training.
2. EHR training should be tiered based on capabilities and workflows of end-users.
3. The training methods, providers, content, timing and ongoing plans will impact on the overall effectiveness and should be considered.

3.4 Support

As well as training, ongoing support is important to help end-users to solve problems and better utilise the EHR system and to create an optimal environment for EHR success [10-13, 32, 33, 43, 50, 51, 95]. Support of end-users both before and after EHR implementation has been shown to improve user acceptance and adoption of the EHR system, resulting in a more successful implementation process [95]. This includes support from IT staff, peers and colleagues, management and policy-makers [18]. At the procurement stage, the level of support being supplied by the vendor needs to be decided. Whilst local on-site support at time of Go Live is a critical factor [104] and 24 hour support is recommended at Go Live (approximately 3-4 weeks) [33, 79], this level of support may be tapered off over the first 6-12 months [12, 41].

3.4.1 Expert Support

Expert support assists end-users to solve problems and optimise their use of the EHR system (e.g., use of shortcuts), which differs from IT support [10-12, 32, 49]. It has been recommended that these support staff, who are often referred to as super-users, are peers or supernumerary staff members who receive extra training to enable them to provide frontline support [84, 86, 98]. Other responsibilities of super-users vary depending on the healthcare setting and could include project liaison between EHR developers and the clinical team, being a facilitator during EHR training sessions, a role model for colleagues to help foster acceptance of change [98], developer of user manuals specific to the clinical setting [99] and reviewer of competency checklists for each clinician in their clinic area [84]. Whilst, super-users could make good champions, their roles and responsibilities differ as they are a point-of-contact

support on the floor and their roles should be distinctly outlined from the outset for pre and post Go Live [107].

Managers and super-users should be made aware of the super-users' responsibilities and the associated time commitments to ensure the most appropriate person is appointed and that managers support super-users to manage their clinical workloads in conjunction with their support role [84, 86]. Where possible, end-users should be encouraged to volunteer for this role to help them see it as an opportunity rather than a burden, as this role can be both physically and emotionally draining [86]. It is recommended that super-users not only have IT skills but are also respected by others, have good problem-solving and interpersonal skills, provide proactive support (especially to individuals who may be struggling with change), employ teaching strategies which involves sharing of information and promoting "learning-by-doing", report problems to appropriate technical staff who can fix it, and retain a positive framing of the EHR as they are an important social influence to other users [86, 98].

It is very important to ensure super-users are ready and available on the day of Go live, and that end-users are aware of who the super-users are, with some implementation sites using t-shirts [106]. Staff rotas need to be done well in advance of Go Live to ensure super-users maintain minimal to nil patient load during Go Live [74] and are on duty during all clinical shifts at time of Go Live (i.e., 24/7 seven days a week in an acute hospital) [101, 106]. A ratio of super-users to total number of end-users of 1:5-8 has been recommended in the literature [74, 84, 94, 106], and the most appropriate ratio may be determined by managers based on level of skills and experience amongst their staff [84]. For some sites, the help of current staff was sufficient, whilst others needed to hire or contract staff to provide additional on-site support [104]. Where super-users are trained prior to general end-users which was recommended in the literature, they may also provide feedback on the system and the training sessions [84], however, training super-users too early could necessitate provision of refresher training sessions prior to Go Live or weekly engagement sessions to retain their knowledge [84, 106]. Overall, vendors encourage the appointment of super-users [62], however, there is varying evidence related to the efficacy of super-users in primary care settings which may be related to the appropriateness of those selected [108].

3.4.2 Technical Support

Technical support refers to the provision of assistance from IT staff from the healthcare organisation, the Vendor or an outsource provider [12]. Provision of technical support helps to reduce disruptions to workflows [41, 47], and absence of appropriate technical support during the first few days of system operation can be disastrous for an EHR implementation [8]. An IT service management/operations team may include a Service-desk Manager, Service-desk operators, IT engineers and application support [69]. Employing IT support within the healthcare organisation who work directly with the HCPs throughout the development and implementation phases and learn the workflows is recommended, however not always feasible [49, 51]. Smaller organisations may have less access to staff with technical skills [49, 51], whilst larger organisations also find it difficult to retain good IT staff as private sectors would pay more for their skills and additional incentives may need to be offered such as flexible jobs and clear career pathways [45, 60]. Therefore in primary care settings, software vendors are often the main or only source of formal support available to end-users [33, 62] and whilst technical support staff from the vendor can help with initial implementation issues, the literature suggests that vendors supply poor follow-up support including staff who do not understand the clinical workflows of that organisation [49, 98].

Technical support may be provided via personal contact (i.e., on-site) or written documents (i.e., user manuals) [95]. If the technical support fails it will result in frustration amongst end-users and potential safety risks, and therefore needs to be carefully planned [18]. During the initial stages, IT staff will need to respond to urgent requests which may have safety implications [12], and therefore, it has been

recommended that technical support is available in real-time, 24 hours a day, 7 days a week [11, 32-34], at least on an 'on-call' basis [104]. However, this level of support is costly, especially if IT staff are being outsourced and therefore, consideration should be given to how long it is required after the initial days and weeks of EHR Go Live [11, 51, 95]. Other options include provision of support via a telephone help desk and additional impersonal support provided via resources such as training workbook, help menu within the system, a website with information and a user manual which is provided as a printed document as well as a PDF file [99, 104]. Where possible, support staff should possess good communication skills and understand the clinical workflows in order to adapt the system for various end-users [104]. The level of support required will vary depending on the healthcare context, risk of safety issues and stage of implementation.

3.4.3 Other Support

In addition to expert and technical support who respectively assist end-users to optimise their use of the EHR and with IT issues, other support is required outside of the IT support remit [104]. This may include Wi-Fi connectivity and power supply issues. Although these may have been in situ prior to the EHR, there will be additional demands on teams managing maintenance, networking and server/platforms for an EHR implementation. Additionally, end-users should be aware of which support to contact regarding issues with connectivity versus the EHR, as this usually is not be covered by the vendor's service agreement [104].

Key Findings for Support:

1. Support should be available on every shift during EHR Go Live (i.e., 24/7 seven days a week in a hospital).
2. End-users require different types of support which include how to optimise their use of the EHR and technical issues.
3. Support staff should be employed by the organisation where possible, however, this is not always feasible and support staff may need to be contracted from an outside provider.

3.5 Resourcing

Sufficient financial, time and workforce resources must be available to sustain a successful EHR implementation [9, 12, 32, 43, 47, 49, 52, 71]. The following sections discuss the literature around the importance of each of these resources.

3.5.1 Financial

Inadequate funding is reported as a huge barrier to EHR implementation, especially for smaller organisations [12, 32, 47, 49, 52, 71], and the size and complexity of organisations may necessitate greater implementation costs associated with system integration [69]. There are huge start-up costs associated with acquiring the required infrastructure and skilled personnel [9, 12, 33, 41], as well as ongoing costs to maintain and upgrade the system to keep it working effectively [33, 47, 49, 96]. According to the literature, there is usually a delay in obtaining any return on investment, as well as a loss in productivity during implementation [8, 71] and it has been suggested that half of all large IT projects go beyond their original budgets by 45% [109]. Specification scope creep can often be the cause of organisations exceeding their budgets [9, 71, 100], and thus, planning for contingency expenditure is recommended [68]. Prior to procurement, an organisation must assess their financial resources, perform a cost analysis to make a business case and avoid scope creep with significant planning [32, 41, 69, 110]. Costs related to infrastructure and personnel amongst others need to be considered when budgeting for EHR implementation [68, 69] and some considerations related to these costs are discussed in more detail below.

(i) Infrastructure Costs

Both hardware (e.g., computers, printers) and software licences (e.g., EHR and speech recognition software) will need to be purchased during EHR implementation (*see Section 5.3 Infrastructure),* as well as furniture to accommodate the use of this new hardware [68, 69]. The cost of the infrastructure will depend on the stage of technological maturity and the size of the organisation, the requirements of the software application being implemented, the products currently available on the market, the physical requirements of the wards, rooms or offices, and the needs and preferences of end-users [69]. Although some infrastructure may be in place (e.g., computers, wireless network, administrative software) it has been a common occurrence that healthcare organisations have to upgrade their wireless connection and replace hundreds of PCs due to lack of compatibility with mobile devices or the EHR software, and these costs may not have been included in the initial budget [68, 69]. To help reduce or maintain costs associated with infrastructure, the following has been recommended in the literature:

1. Any hardware purchases prior to EHR implementation should meet the latest requirements of the EHR vendor and other software products which may be used [68, 69].
2. Vendors often providing discounts for bulk purchases and thus, organisations should procure products together where possible [68].
3. Ensuring all systems purchased meet the interoperability standards can reduce costs in relation to middleware and adapting software [5, 41, 49, 50].

As technology develops, other more cost-effective options are also being introduced to reduce infrastructure costs such as cloud computing which helps to eliminate installation and maintenance costs [71, 111]. Costs associated with infrastructure are not a once-off-payment, and maintenance, improvement and upgrade costs also need to budgeted [69].

(ii) Personnel Costs

Costs related to personnel will vary depending on the number of new roles created (e.g., project management team, IT operations) and whether these posts will be temporary, permanent or outsourced [69]. Some examples of decisions which will impact on the personnel costs include:

- Staff backfill to enable HCPs to fulfil roles which takes them away from their clinical role (e.g., Clinical Champion) [68] or to attend training will be costly but may reduce impact on productivity and improve training attendance [33, 41, 69].
- Provision of training via one-to-one sessions will be more expensive than class-room based sessions, but may be more effective [33].
- Additionally, data migration from paper-based to electronic records also comes with a large cost [68, 69], especially if old charts are scanned into the EHR [80, 82].

In addition to initial costs, there will also be ongoing staff training and support required as well as IT services for optimising the EHR and testing new functions [69, 96, 101]. For example one site reported a median of 72 significant changes made to the EHR per month over the first 6 years of implementation [112]. To reduce personnel costs, affiliated healthcare organisations have shared staff to provide training or support and shared policies and workflows [9, 32, 33, 67].

(iii) Other Costs

Many other costs will also need to be considered including space to accommodate the work and the testing of products and training of end-users, which will grow as teams expand during the implementation process [69]. If end-users need to travel to the training sites, overheads may also need to be covered [68]. There will many other consumables which need to be budgeted for, including printing and developing of training materials including e-learning modules [69] and allocation for formative and summative evaluations of the benefits, costs and end-user satisfaction [59].

3.5.2 Time

It should also be noted that Go Live is only the beginning, and timelines and planning need to expand long past this date in terms of support, training and testing [59]. Facing rushed timelines [33] or experiencing delays [8, 69] have been reported as issues which impact on a successful EHR implementation. During the centralised national EHR implementation in the UK, it was reported that not allowing enough time to engage end-users, failing to check progress against expectations, and setting a too ambitious timeline were some of the contributing factors to its failure [20]. Delays can impact project momentum, end-user engagement and concerns, and training [45]. However, strict adherence to timelines when the organisation was not ready, resulted in a well-documented case at Cambridge in the UK in 2014 [45].

Organisations need to allow some flexibility in their schedule and allow for adequate time for the purchase, development, configuration, design, training and transfer of information from paper to electronic [12, 13, 47, 49]. The experience of other organisations can assist organisations in planning timelines [64, 73]. There also needs to be incorporation of adequate time for HCPs to be involved in each phase of implementation and be given time to learn [9, 11, 12]. It has been recommended that the timing for Go Live is not during winter or doctor rotation change-overs, which are often an already busy time for the organisation [45]. Planning the deployment of resources at key points in a digital change project is also key to mitigating risks [61]. The Wachter report in England has recommended that the EHR implementation is conducted in a staged fashion which acknowledges that organisations who are not ready need to be encouraged and supported to build capacity which takes several years [59].

3.5.3 Workforce

Digital transformations are about more than financing, they require organisations to have the right people, assets and skills, and a clear but adaptable plan for deploying these [61]. Human resources are very important during EHR implementation, and staff shortages and high staff turnover will add substantial challenges to an implementation [9, 13, 32, 47, 52]. Additionally, lack of expertise in the area of healthcare informatics has been noted in countries such as Canada [19] and the UK [60]. Where possible healthcare organisations should invest in their existing workforce to develop the skills needed in relation to IT, training, support, change management and an understanding of clinical workflows [49, 60, 69, 71, 96]. Whilst this requires reconfiguration of the workforce [59], it can reduce dependence on vendors for support and maintenance [32]. During the EHR implementation, additional staff will likely need to be employed and this may include the EHR project management team, trainers, testers, support staff, back-fill staff (e.g., during training and to cover the clinical loads of champions) and software developers [69].

Key Findings for Resourcing:

1. Financial, time and workforce resources are required to facilitate a successful EHR implementation.
2. A cost analysis of the EHR implementation should be completed with consideration of a contingency budget, and scope creep should be avoided where possible during the EHR build.
3. Whilst the implementation team should meet deadlines, Go Live should not occur until the organisation is ready.
4. New roles and reconfiguration of the workforce will be needed to ensure adequate staff and support, and where possible, organisations should develop the skills required for these roles within their current workforces.

3.6 Workflows

Compatibility of the EHR system with the organisation and end-user workflows is of utmost importance for a successful EHR implementation [9, 10, 41, 50]. Often EHR failures are in fact failed workflows rather than failed technology [113], and this in turn can negatively impact efficiency, productivity and end-user satisfaction with and acceptance of the EHR [10, 12, 43]. In Australia and the UK, over-reliance on the design of the digital solution and the maturity of the commercial software product rather than the 'end to end' value proposition at a workflow- and process-level, reportedly resulted in HCPs distrusting the national system and not seeing value in changing their way of operating [16]. This can also result in end-users incorporating 'workarounds' into their practice such as using paper to document patient encounters and later transferring this information into the EHR [114, 115]. End-user workflows will inevitably change with the implementation of an EHR and due to the somewhat fixed nature of technology and the quest for interoperability and improved patient care, it is not always possible to meet every workflow and need of the organisation and end-user [47, 96].

Aligning the EHR with existing paper-based practices may minimise disruptions for end-users [12, 13, 18, 41], however, implementation of an EHR provides a unique opportunity to update current non-standardised practices, embed best practice standards and identify any inefficiencies and safety issues [18, 41, 43, 45, 80]. In fact, healthcare organisations which redesigned their work processes during an EHR

implementation have reportedly experienced smoother transitions to EHR use [13]. Additionally, achieving uniformity in processes, standardising routines and information flows using the EHR, is a critical factor which is required to facilitate interoperability [18]. Therefore, whilst radical re-design of work processes should be avoided [71], some changes to end-users' workflows will be required to facilitate collection of more consistent quality data in terms of language, measurement values and structure [15, 33, 114, 116]. End-users can be assisted with new work processes via ongoing training coupled with support, and they should be informed of why these changes were made and the benefits associated with these changes (e.g., use of structured data field to automatically populate a discharge letter) [33, 62, 71].

Workflow analysis should be part of the system design and driven by patient-orientated workflows (i.e., healthcare episode) rather than being data or process-driven (i.e., ordering a blood test) [18, 114]. Understanding existing workflows is important for EHR design and to improve how HCPs work [43, 45, 103]. To define the workflow of HCPs in each context, the following steps have been recommended by HIMSS [117]:

1. Analyse current workflow (from front-desk admission to prescriptions).
2. Explore end-user input regarding roles in current paper workflows.
3. Review and finalise documentation of current workflow.
4. Identify waste and opportunities; then redesign workflow.
5. Identify and implement the EHR system and new workflow (with necessary support and training).
6. Analyse new EHR workflow and refine as needed.

Mapping of existing workflows has been performed via direct observation, interviews, surveys and simulation of clinical scenarios [118-120], and should be conducted by technology mediators who understand the end-users' workflows [33]. This will uncover any variations in practice amongst HCPs in the same setting, as well as any inefficiencies or unsafe practices [45]. Study of workflows should also consider how this workflow is impacted under different circumstances (e.g., new patient versus return patient) [121]. In addition to the current paper-based workflows, use of the EHR should be simulated using clinical scenarios to assess the impact of the device, physical layout of room or ward [122], and disruptions (i.e., patients or other staff) [123] on workflow efficiency, the communication between HCPS and downstream processes such as administrative operational processes [33, 41, 71, 124]. In addition to work processes, end-user thought processes should also be considered, for example to reduce alert fatigue, identification of clinician thought processes can help identify the most appropriate time for alerts regarding medication [103]. To facilitate adaptation of the EHR to end-user workflows within the specific organisation, the product needs to be flexible *(See Section 5.5 Adaptability)* and fixed solutions should not be imposed on HCPs [41, 61]. Overall, workflow analysis should be an ongoing process post implementation to identify any workarounds and optimise workflows and the EHR [45].

Key Findings for Workflows:

1. The EHR should fit with the workflows of the organisation and end-users.
2. Workflow analysis should be performed with workflow optimisation completed where possible.
3. Disruptions to end-users should be minimised but to obtain the benefits of an EHR some changes to workflows will be inevitable.

4 Human Factors

The ability of healthcare organisations to successfully adopt an EHR system will be massively determined by the end-users of the system [9]. Despite the organisational resources and structure, and the technology procured, human factors and how the technology interferes with the end-users' values and roles, will determine their acceptance and support of the system [39]. The Human Factors were identified under three domains:

4.1 Skills and Characteristics

Individual characteristics and skills of end-users impact their ability to operate the EHR, as well as their attitudes towards EHR implementation [9, 11, 13, 41, 45, 49, 96]. A lack of basic computing and keyboard skills has been reported as a substantial barrier to EHR adoption amongst end-users [13, 32, 49], and prior computer experience is now considered an aspect of the technology acceptance model [95]. However, many end-users of EHR systems will have received their qualifications before IT programmes were introduced [125], and a lack of IT experience and support is thought to be an even more widespread issue in smaller, more rural organisations [51, 85]. Although, there is some evidence reporting that younger individuals find it easier to become accustomed to using an EHR, this research is inconclusive [13, 126], likely due to the many other confounding factors including the usability of the system, quality of training and support provided [12], and individual characteristics [41].

Personal characteristics which reportedly predispose an individual to adopt and accept an EHR include being: change-orientated, flexible; a team player; willing to ask for help; and a problem-solver [85, 86]. It is very important to note that resistance-to-change is not always solely due to an individual's personality, and may also be related to user concerns and poor functionality or usability of the EHR [9, 47]. Additionally, prior experience of using an EHR system may reduce the uncertainty and disturbances for end-users [12, 32]. However, the effect of prior experience is not always a positive one, as end-users may have been accustomed to their old system and identify shortcomings in their current system [34, 86]. To improve end-user IT proficiency and manage individuals' responses to EHR implementation, the literature has discussed design of a usable and intuitive EHR system, provision of good quality training and ongoing support, and investment in change management. Whilst training, support and usability are discussed in individual sections, the human aspects of training as well as change management are discussed in more detail below.

Training

According to a KLAS report, training is the lead driving force for high end-user satisfaction with the EHR [102]. Good quality training can improve the end-user's proficiency, accuracy, time management and satisfaction [12]. End-users will present with varying levels of IT proficiency and experience, and where end-users struggle to grasp basic EHR functionality of accessing screens and navigating the system, they will find it more difficult to learn how to document patient care [84]. Whilst some end-users will learn faster than others [84, 94], even the most adept computer users find it challenging to type notes

and navigate the complex EHR system while concurrently listening to patients' complaints, assessing medical relevance and contemplating interventions [11]. Therefore, irrespective of IT self-efficacy or EHR experience, training and support should be provided to all end-users from HCPs to administrative staff [34, 41, 49, 85]. Multiple aspects of training should be considered to provide the most effective training to all end-users which maintains their engagement including the following identified in the literature:

- All parts of the EHR system should be ready at time of training [100] and should be intuitive and simple to use [11, 13, 33, 49, 51, 127, 128].
- Identify learning needs of end-users by assessing competency with the EHR system pre and post training [106].
- Provide basic computer literacy training prior to EHR training for those requiring it [32, 52].
- Tier EHR training based on end-user skills [33, 34, 41, 50, 52, 60, 85, 101].
- Tailor training to the specific needs of each profession and their workflow [33, 51, 94, 101].
- EHR training should be provided as close to Go Live as possible (within 6 weeks) [12, 32, 34, 85, 94].
- Training should be mandatory for all to attend and ensuring allocation of time outside of clinical workload and/or incentives to attend is often required [9, 41].
- Several methods of training may be utilised for different aspects of EHR training (e.g., e-learning for basic functions and classroom or one-to-one for specific functions) [94].
- End-users should have time to practice using the EHR prior to Go Live (e.g., drop-in clinics) [12, 13, 102].
- Refresher training should be provided to optimise use of the EHR [11-13].

Change Management

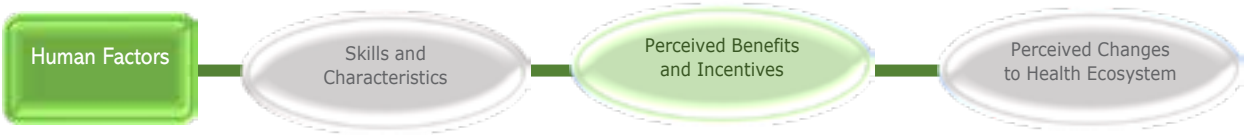
Whilst the technology is the tool to enable change, change management is the application of a set of tools, processes, skills and principles to help manage the people side of change and achieve the required outcomes [60, 73]. No single approach to change management will suit each individual [42] and different approaches will need to be taken [45], however, the following has been recommended in the literature and could be utilised by the change management team:

1. Create a climate for change:
   - Leaders at all levels should be present and demonstrate that the EHR is their highest priority [9, 32, 74, 87].
   - Establish a sense of urgency (i.e., need for the EHR) amongst frontline staff [73].
   - Create role-models for end-users (e.g., champions) who have facilitating personal attributes such as being flexible and change-orientated [73, 85, 86].
   - Create a clear and consistent vision of what an EHR will look like [12, 32, 71, 73, 88].
2. Engage and enable the organisation:
   - Communicate the 'Future State' using methods which suit the practice culture (e.g., vendor demonstrations, videos, role-playing, or have staff visit live sites [73].
   - Empower and involve end-users in accomplishing the 'Future State' [9, 32, 43, 73].
   - Plan for and create short-term wins and celebrate these wins (e.g., Go Live, quality improvements) [9, 12, 32, 73, 74, 87].
3. Implementing and sustaining the changes:
   - Focus on problem areas, promote solutions and help change individual behaviour to achieve organisational goals [73].
   - Prepare to train, retrain and provide technical assistance to rapidly address problems [73].
   - Regularly celebrate the successes of the EHR [73, 88].

Key Findings for Skills and Characteristics:

1. End-users with low levels of computer skills may struggle with the EHR unless they receive basic computer training in addition to EHR-specific training.
2. Personal characteristics of end-users affect their openness-to-change and the EHR, and organisations should recognise these characteristics when appointing champions and super-users.
3. The usability of the EHR as well as the training, support and change management will all be important to improve end-user acceptance of and satisfaction with the EHR.

4.2 Perceived Benefits and Incentives



Although the EHR technology must be seen as mandatory to use, the perceived benefits of using the EHR can significantly impact on its acceptance amongst end-users [9, 12, 41, 50, 129]. Benefits related to care delivery tend to be of more interest to HCPs as opposed to cost savings and thus, benefits such as improved data quality, automation of mundane tasks and patient safety need to be demonstrated to them [12, 13, 43, 45, 95]. Unsuccessful implementations have discussed the limited understanding of the software and of how the system could benefit HCP practices amongst end-users as one of the contributing factors to failure [50] and poor demonstration of the added value attributed to resistance by doctors in both Germany and Canada [19]. On the other hand, where end-users have unrealistic expectations of the EHR, failure to meet these has resulting in low end-user satisfaction with the EHR [41, 45, 50, 96]. Additionally, increased societal use of technology may be a contributing factor to rising HCP expectations regarding what technology should be available at work [66].

Benefits of implementing an EHR can also be demonstrated in the form of incentives and provision of incentives has been useful to encourage EHR optimisation internationally [9, 12, 41, 50, 129]. Incentives for HCPs to implement and adopt EHRs can come in the form of monetary compensation, reimbursements, pay-for-performance, sponsorship benefit packages, bonus incentive plans, promotion and career development opportunities, managerial praise and recognition, as well as intrinsic rewards emanating from job satisfaction [13, 18, 41, 43, 47]. These incentives can motivate individual HCPs to participate in collaborative networks and to use the service [130]. Whilst incentives for EHR use have mainly been utilised in the US as seen with the HITECH Act [18], incentives have also been utilised in the UK to ensure GPs only purchase NHS-accredited EHR systems [59] and in Denmark to engage GPs with sharing health records [18]. Where no incentives were provided, this has been previously construed as a lack of priority for both the work involved in implementing EHRs and the data collected [13], and has resulted in limited and less integrated use of EHRs [13].

It has been difficult to convince end-users that the disruption and changes to work practice that they must experience during an EHR implementation are worth the benefits [131]. Therefore, the perceptions of end-users regarding the benefits and realistic timelines for realising those benefits need to be addressed as soon as possible via good communication from leaders, and support and training staff [41, 45, 50, 129]. The realistic benefits shared with end-users may include:

- Improved end-user efficiency (e.g., auto-population of data fields and shortcuts) [7].
- Increased access to information at point-of-care [5, 8-14].
- Decreases duplication in tests and work [1].
- Additional safeguards for protecting patient information [132].
- Improved patient safety and quality of care [5, 8-14].

However, end-users should be aware that there will be a learning curve and adaptations to the software will be required even after Go Live [101]. For example, in a case study in England they set a realistic goal after Go Live of being back to the pre Go Live productivity state after four months, rather than end-users expecting improvements in that short period [131]. To maintain positive perceptions regarding the benefits of an EHR after the EHR has been implemented, organisations should publish the quality outcomes and demonstrate success to improve end-user satisfaction and mitigate any concerns [11, 43].

Key findings for Perceived Benefits and Incentives:

1. Perceived benefits of the EHR will impact on end-users' acceptance of and engagement with an EHR implementation.
2. Potential benefits of an EHR and realistic timeframes for achieving these benefits need to be shared with the end-users throughout the project.
3. Incentives for end-users have been useful when engaging small practices with interoperability standards and ensuring they can participate in health information exchange with larger organisations.

4.3 Perceived Changes to the Healthcare Ecosystem

There is no denying that healthcare IT systems significantly change the organisations in which they are introduced, and can profoundly alter routine workflows of HCPs [42]. These changes to patient data management, patient interactions and the roles and responsibilities of HCPs have caused concern to HCPs which can impact on a successful EHR implementation [9, 11-13, 32, 34, 47, 49-51, 95, 96, 128, 133]. The following concerns were highlighted by the identified literature reviews and are discussed in further detail below: (i) Data Privacy and Security; (ii) Patient-clinician Relationship; and (iii) Roles and Responsibilities.

(i) Data Privacy and Security

Personal health information is regarded as the most confidential of all types of personal data [134], and a national EHR expands the capacity of information systems to capture, use and exchange this sensitive data across organisations [135]. Therefore, it is perhaps unsurprising that HCPs have been concerned regarding the risk of compromising the privacy and security of personal health data with unauthorised access [9, 11-13, 32, 34, 47, 49-51, 95, 96, 128, 133]. Many of the issues reported in national EHR implementations across the UK, Germany and Australia revolved around data privacy and security concerns amongst front-line staff as these concerns were not addressed [19, 20, 42]. A secondary concern also reported in the literature is that a breach to data protection could make HCPs liable [18, 41, 51, 96, 129]. Whilst patients were not as concerned with data privacy concerns of the electronic record stored within the healthcare organisation, data privacy concerns were reported by patients in relation to the use of patient portals [12]. In addition to end-user concerns resulting in poor adoption of EHRs or patient portals, where HCPs reportedly had concerns regarding external agencies accessing patient data, they have sometimes omitted sensitive and stigmatising information [13].

Once end-users' begin using the EHR, their concerns are usually mitigated and they begin to see the EHR as improving the security and confidentiality of patient records [13]. However, prior to

implementation, according to the literature, other ways of reassuring end-users regarding data privacy in the EHR include:

1. Any data privacy and security concerns should be addressed during training sessions and by champions and super-users [32, 95].
2. A disaster recovery plan or drills should be tested with HCPs routinely [136].
3. End-users should be informed of and understand:
   - Robust privacy policies and regulation [13, 32].
   - Additional safeguards of using an EHR (e.g., role-based access control) [132].
   - Physical and technical security elements used to mitigate a potential cyberattack [134].

(ii) Patient-clinician Relationship

HCPs also report concern that using the EHR during patient encounter could negatively impact on their relationship with that patient [11, 13, 18, 34, 41, 49, 51, 128]. There is evidence to support this concern with both patients and observers in research studies noting the change in the HCPs interpersonal skills compared to paper-based clinical documentation (Table 3) [104, 137, 138]. However, the EHR also provides unique opportunities to educate patients and improve patient care with CDS or alerts triggered via point-of-care data entry [137, 138, 140]. Despite the potential negative impact on patient-clinician communication, use of the EHR during a clinical encounter reportedly did not affect overall patient satisfaction, and patients were reportedly supportive of the benefits associated with EHR use in this study [138].

Table 3. Impact of the EHR on patient-clinician communications

Challenges to communication	Benefits to communication
Reduce eye contact [104, 137, 138]	Point-of-care data entry and access [138, 139]
Reduced rapport building and provision of emotional support to the patient [104, 137, 138]	Engaging the patient with their medical record [138, 139]
Structured EHR format and clinical alerts can distract from the patient [137, 138, 140]	Structured formats facilitate gathering and provision of more information to the patient [137, 140]
Less exploration of patient-specific psychosocial or emotional issues [137, 138, 140]	Can use the EHR as an education tool [138, 139]

Alternatives to navigating the EHR during a patient encounter have also been suggested in the literature, such as only using the EHR after the patient has left [138], speech recognition technology which can dictate spoken word into the EHR [140] and clinical scribes who are employed to transcribe on the behalf of the HCP in real-time [141]. However, this results in the EHR not being used to its full potential [142]. Therefore, to mitigate negative effects on patient interactions whilst gaining the benefits associated with utilising the EHR during a patient encounter, the following has been recommended in the literature:

1. Easy-to use EHR [140].
2. Improve end-user competence with EHR use with adequate training and support [137, 140].
3. Train users on how best to interact with patients while navigating the EHR [7, 13, 104] (e.g., blind typing, screen-sharing to boost patient engagement in their management [13, 104]).
4. Adapt the device and environment:
   - Mobile devices facilitate screen sharing with patients [143, 144].
   - Tablets enable HCPs to retain eye-contact when navigating the EHR [143, 144].
   - Stationary computers should be positioned to ensure HCP remains facing the patient [140, 145, 146].

In conclusion, whilst use of the EHR during a patient encounter could negatively impact on patient-clinician communications, and the benefits associated with point-of-care data entry and access may

outweigh the risks which can be mitigated with improved computer skills, a usable system and adapting the device and environment.

(iii) Roles and Responsibilities

HCPs have also reportedly been concerned regarding the changes to their roles and responsibilities with the introduction of an EHR [11, 18, 41, 51]. Although disruptions to the roles, responsibilities and workflows should be minimised where possible [12, 41], in order to update current practices and align them with best practice, as well as standardise processes to facilitate interoperability, changes to work processes will be inevitable [18, 41, 43, 45, 80]. As discussed in *Section 3.6 Workflows*, changes to workflows can be a major barrier for end-users [18]. These changes may include the clinical data collected and by whom it is collected, however soliciting and using input from interdisciplinary sources can be a cultural change for many small practices [73], resulting in HCPs feeling threatened and being reluctant to embrace the change [8, 73]. Additionally, these changes to work processes will initially be more time-consuming for end-users, resulting in HCPs spending more time on administration work as opposed to seeing patients [18]. This increased workload is also of concern to HCPs [12, 47, 128]. Advances in technology also sees artificial intelligence (AI) being incorporated within the EHR [147]. This includes the use of clinical decision support (CDS), and HCPs have reported feeling threatened by this technology and are also concerned regarding patient safety with its use [9, 47, 51, 96].

To address the end-user concerns while ensuring safe and beneficial technology is developed, the following has been recommended in the literature:

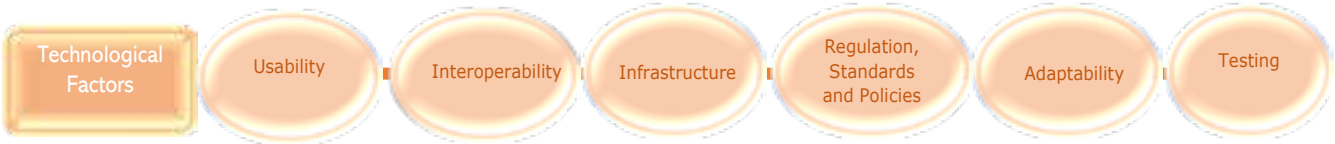
1. User involvement in workflow development as well as new technologies such as CDS:
    - Empowers end-user with sense of ownership over the technology [8].
    - Maximises benefits and mitigates potential safety risks of technology [103].
    - Promotes adoption of the functions and reduces waste of time and money on functions which do not meet end-users' needs [12, 148].
2. Concerns should be addressed during training sessions and by leaders and support staff [32, 95].
3. Development and employment of international guidelines in developing new technologies such as the European Commission expert group recommendations on AI [147].
4. Provide end-users with evidence to support the use of such technologies [149].
5. To improve usability and end-user satisfaction with changes to workflows in the EHR, personalisation of data input, data output and workflows should be enabled and end-users should be educated in its use [150].

Key findings for Perceived Changes to the Healthcare Ecosystem:

1. Introduction of an EHR brings changes to the way personal health data is managed, the HCP interacts with patients, and the roles and responsibilities of HCPs, which creates concerns amongst end-users.
2. All concerns of HCPs should be addressed and managed by leaders, trainers, and support staff prior to EHR implementation.

5 Technological Factors

The technology the end-users utilise will impact on their overall satisfaction, as well as the effectiveness and efficiency of the EHR [39]. Therefore, technological factors are intrinsically linked to the human and organisational factors [9]. The following technological factors were identified in the literature and by the Advisory Group:



5.1 Usability

Usability is a critical factor which influences the satisfaction and concerns of end-users with the EHR system [10, 43, 128]. Additionally the usability of the system will impact on end-user efficiency, patient-facing time [11, 13, 33, 49], quality of care [11], relationship with the patient [71] and most importantly, patient safety [33, 151]. The Healthcare Information and Management Systems Society (HIMSS) has defined usability as: *"the effectiveness, efficiency and satisfaction with which specific users can achieve a specific set of tasks in a particular environment"* [127]. The primary role of HCPs is to assess and treat patients, rather than spend their time navigating the EHR [123], therefore in addition to screen design elements of the EHR interface such as colour, font and iconography, usability principles identified in the literature are shown in Table 4.

Table 4. Principles of EHR usability identified from the literature

Simplicity	Interfaces should be simple and show important information to avoid overwhelming users e.g., avoid long lists or too many options [10, 11, 13, 49, 71, 127, 128]
Naturalness or Intuitive	Interfaces, navigation and features should be intuitive to clinical workflows [11, 13, 33, 49, 51, 123, 127, 128]
Consistency	All parts of the application have the same look and feel e.g., consistently using the same terminology and data entry fields [127]
Forgiveness and Feedback	Allows end-users to recover from errors easily and informs users of actions [127]
Effective Use of Language	User-friendly language which also provides mapping to standardised codes and terms for data retrieval [127]
Efficient Interactions	Number of clicks or steps required should be minimised (e.g., not entering data multiple times), navigation options such as shortcuts should be offered (e.g., frequently searched terms appearing at top of list) [71, 95, 127, 152], and tap and swipe capabilities have been recommended [123]
Effective Information Presentation	Clear fonts and visually appealing elements to allow users to easily consume information and identify abnormal clinical values [127]
Preservation of Context	Interface includes minimal screen changes and visual interruptions while HCPs are completing tasks, which allows end-users to focus on the content of the workflow rather than acclimating to a new environment after every action [127]
Minimize Cognitive Load	Interface should be cohesively aligned with tasks (e.g., end-user should not have to access multiple screens simultaneously, alerts should be concise, informative, and appropriate, and the EHR should provide automatic calculations where appropriate) [127]
Ease of access	Login process and availability of devices for access [13, 95]
Data availability	All necessary patient information should be available at all times [43]
Interoperability	Ability to share information between systems within the same organisation or across organisations [127]
Personalisation	Ability of end-user to customise how data is input or viewed [123, 150, 153]

EHR software comes "off-the-shelf" and requires customisation to ensure the system is usable in the specific context it is being deployed (e.g., suitability of role-based access). Poor usability can lead to unsafe workarounds by HCPs which could include HCPs retaining their old paper-based processes and scanning the documents into the EHR [12, 32, 33, 51]. This is a safety risk as critical information may then not be flagged in the EHR and could be missed (e.g., allergies) [12, 32, 33, 51]. Where EHR systems have been cited as difficult-to-use, EHR projects have been abandoned such as the PHR 'Healthspace' in the UK [91]. Additionally, in the US difficult-to-use EHR systems and the clinical documentation burden led to the need for developing a new role referred to as a clinical scribe, an individual who transcribes clinical information in real-time and helps HCPs to navigate the EHR [141].

To ensure the development of a usable EHR system for end-users, workflows need to be identified and analysed, and end-users need to be involved during the development of the EHR to ensure the EHR supports their cognitive and clinical needs [9, 33, 41, 89]. Even with workflow analysis and end-user involvement, usability testing is required and considered a mandatory element of user-centred design by the Office of the National Coordinator of Health Information Technology EHR Certification Program [90]. This will require heavy time and financial resourcing and therefore, where possible sharing of information regarding usability is recommended across healthcare organisations [9, 33]. At times, EHR developers will need to balance the development of a usable system with the need for interoperability and security. For example, complex login processes and short logout times may be required for security purposes, however this may reduce end-user satisfaction with the EHR [11, 71]. Additionally, although end-users may find unstructured data entry templates easier to use than structured templates [104, 154, 155], structured data elements may need to be collected to enable other data fields to be automatically populated in the EHR (e.g., problem lists) [155-157]. However, enabling personalisation of data input (e.g, templates, order lists), data output (e.g., report views) and EHR workflows (e.g., layouts) ensures the required data is still collected but individual end-users can visualise and retrieve information in a more usable manner and use of personalisation reportedly improves the usability and functionality of the EHR interface [150, 153].

Although an EHR may appear usable at time of development, it needs to be tested within the environment it will be used [97] and end-users need to be trained and supported to ensure they can navigate the system and use it to its full capacity [9, 33, 41, 49]. Usability testing and optimisation is not only conducted during EHR implementation but is an ongoing process for the lifespan of the EHR [33, 97].

Key Findings for Usability:

1. To be considered usable, the EHR should be effective, efficient and satisfy the needs of end-users.
2. End-user involvement, workflow analysis, end-user training and support, and ongoing usability testing have been recommended to ensure EHR usability.

5.2 Interoperability

One of the benefits of an EHR includes health information exchange (HIE), which is the ability to share accurate patient data across organisational and geographical boundaries at all times along the patient care pathway [5, 13, 15]. This requires systems to 'talk' effectively to one another which is referred to as interoperability [10, 12, 15]. Interoperability is considered a quality attribute in EHR system evaluations and a critical factor for EHR adoption [10, 12, 15].

HIMSS has been defined it as: *"the ability of different information systems, devices or applications to connect, in a coordinated manner, within and across organisational boundaries to access, exchange and cooperatively use data amongst stakeholders, with the goal of optimising the health of individuals and populations"* [158]

The European eHealth Network has broadened this definition beyond the ICT systems to define it as: *"the ability of disparate and diverse organisations to interact towards mutually beneficial and agreed common goals, involving the sharing of information and knowledge between the organisations, through the business processes they support, by means of the exchange of data between their respective ICT systems"* [14]

Interoperability encompasses more than data sharing across organisations, it includes the integration of existing systems within an organisation with the EHR (e.g., patient administration and medical imaging) [5], as well as the flow of information from public health databases and mobile monitoring devices [30]. These home monitoring devices as well as other devices which fall under the internet of things (IoT), are rapidly evolving and may be integrated with EHR systems in the future to increase the availability of data to HCPs to base clinical decision-making on [159]. Other benefits of interoperability also exist for patients, HCPs, healthcare organisations, policy makers, regulators and healthcare software suppliers [5] (Table 4). However, where interoperability has not been achieved, it has resulted in poor usability which can lead to patient safety issues, for example having to access multiple screens (i.e., from different systems) [160]. Inconsistent facilitation of HIE across organisations can also lead to uncertainty on the behalf of the HCP and result in poor uptake of functions such as the shared care record and e-prescriptions [129].

Table 4. Benefits and challenges associated with EHR interoperability identified from the literature

Benefits	Challenges
Patients and frontline staff:	**Organisational and human:**
More timely access to information [5, 8-14]	Concerns regarding data sharing and security [12, 13, 45]
Reduction in unnecessary duplication of tests [5, 8-14]	Distrust amongst end-users of data imported external to organisation (i.e., inaccurate or outdated) [133, 159]
Improved safety and quality of care [5, 8-14]	Additional responsibilities regarding data management and maintenance [161]
More continuity of care [5, 8-14]	Lack of relevant expertise, experience and resources (especially in smaller practices) [43, 49]
Availability of remote patient-generated data within the EHR [30]	Inconsistent data capture in incompatible formats [11, 15]
Reduced clinical documentation burden on end-users if EHR-integrated devices automatically populating fields [162]	High costs associated with enabling interoperability [15, 159]
	Local contextual barriers (e.g., lack of communication between public and private sectors)
Organisations and policy makers:	**Technological:**
May be more cost-effective [5, 9-14]	Lack of consistent national and international standards [5, 41, 49, 50]
Eliminates data silos [12, 15]	No unique patient identifiers [59]
Facilitates "mix and match" of EHR components as well as the creation of new functions out of existing ones [14]	Disparate systems and priorities amongst organisations [45]
	Available infrastructure [96]
Increased availability of patient information acts as an incentive to engage the community health services [12]	Use of closed technologies and vendor lock-in [8]

Although some countries have successfully implemented EHR systems (e.g., Denmark, UK, Sweden), no country has achieved a fully interoperable EHR system across community and acute settings [13, 18]. Despite large investment, even America's IT giants such as Google and Microsoft were unable to solve the interoperability and ease-of-use issues [59]. Therefore, interoperability is cited more often as a barrier than as a facilitator to EHR implementation, due to these challenges [10, 12, 41, 49, 96, 128, 129, 163]. The largest barriers have been financial and policy ones, rather than software ones [30], with a lack of international and technical standards being the most cited challenge (Table 4). Although, interfaces can be adapted and middleware can be used to integrate software from two different vendors, this is costly and requires the software to be flexible and adaptable [164-166]. Local contextual factors, as mentioned in Table 4, can impact on successful interoperability and the following are some examples of the challenges introduced by health service ecosystems:

- In the UK where GPs are mainly private practitioners, there has been high EMR adoption rates and data sharing between GP practices but not with public hospitals [59]. To overcome this barrier, GPs must now only purchase NHS-accredited EHR systems and there are penalties for GPs, vendors and suppliers who do not meet the standards for interoperability [59].
- In the private health system in the USA, a de-centralised bottom-up approach to EHR implementation was employed which allowed individual hospitals to independently procure and implement EHR systems. This has made it very difficult to share data outside of hospitals unless they use the same vendor [30].
- Two tier public and private health services in countries, as is Ireland, have reportedly brought additional challenges to interoperability [167, 168]. Stand-alone EHR systems in privately-run hospitals has resulted in siloed information. To combat this challenge which is reportedly mainly related to communication and co-operation between public and private entities, discussions amongst both public and private parties has been promoted as well as ensuring representatives from both private and public settings are present when defining interoperability standards and establishing software certification and testing procedures [167].

Use of shared care records to facilitate HIE across healthcare organisations will require storing and maintenance of the personal health information which is another challenge cited [161]. In countries such as Denmark, the UK, Canada or Australia, shared care data are stored and maintained centrally, and whilst this enables fast access to information, it is costly and a cyberattack would have a larger impact than data stored locally [169]. Alternatively, a distributed architecture may be used where all data is stored locally such as in the Netherlands, and when requested by a HCP in an specific organisation, it goes through a central point [169]. Alternatives have also also become more widely discussed such as a semi-distributed architecture [169] and use of blockchain [159, 170].

Most importantly, interoperability needs to be built in from the start [59]. Although having a single vendor can facilitate interoperability as seen in the US, at present it is unlikely that one system could meet all the ICT requirements of the healthcare organisation covering functions from medical imaging to patient administration [5]. Additionally, although procurement of an EHR may be a long time away for some organisations, introduction of standardised processes and terminologies, as well as purchase of infrastructure compatible with the national interoperability standards may occur well before Go Live [65]. Therefore, the following should be considered prior to implementation of the EHR:

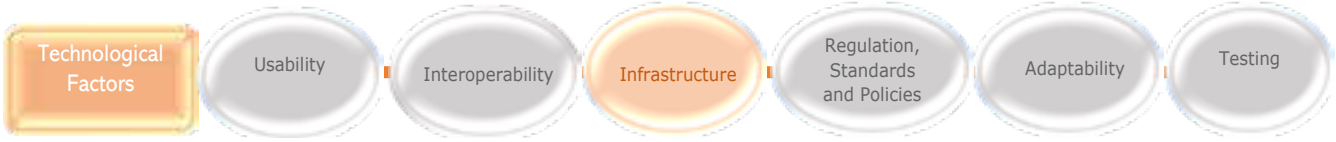
- Technical and data standards should be followed by all vendors and organisations [5, 41, 49, 50], for example open language such as HL7 [171]. To facilitate sharing of information across geographical boundaries, frameworks such as the European Interoperability Framework (EIF) should also be considered [5, 15].

- Local healthcare context: Ireland has a distinctive two-tier public and private health system which sees half the population purchasing private insurance and a large amount of crossover between public and private hospitals [172].
- Collaboration and communication between organisations and stakeholders at different levels, and across private and public sectors, as well as behavioural and organisational change management to overcome the challenge of incompatible data formats, and ensure consistent goals, alignment of work processes, and data quality and integrity [12, 15].
- Balance usability with the quest for interoperability [9].
- High level of quality testing needs to be applied once a system meets the specifications for interoperability as recommended by the EU ANTILOPE project [173].
- Unique patient identifiers are critical to enable patients to be followed from one organisation to another [5, 22].
- Sharing of information across healthcare organisations or between the EHR and integrated devices requires consideration of:
    - Data management either centrally or locally [161].
    - Data privacy and security policies to protect sensitive personal information [135, 174, 175].
    - Shared information must be relevant and meaningful for clinical decision making [18, 30].
- Significant planning and financial investment is required including infrastructure [15].

Key Findings for Interoperability:

1. Interoperability is the ability of different systems to effectively 'talk' to one another and is needed between EHRs at different organisations and between the EHR and existing systems within the same organisation.
2. Collaboration and communication between all healthcare organisations as well as national standards are imperative to facilitating interoperability.
3. Interoperability has been a huge challenge internationally and it needs to be built into the EHR from the start.

5.3 Infrastructure



The availability of sufficient and suitable infrastructure, which includes both hardware and software, is critical to ensure a reliable, functioning and accessible EHR, and thus, patient safety and end-user satisfaction [41, 71, 96, 176]. Whereas, system failures such as breakdowns, errors, re-booting and unplanned downtime which wreak havoc and have potential safety implications [11, 12, 32, 71, 101, 128]. Infrastructure will account for a huge proportion of the overall EHR budget with the updating and purchasing of hardware and software to ensure it is reliable, functioning and accessible and the resourcing required should not be underestimated [60]. Considerations related to the procurement of software and hardware from the literature are discussed below.

(i) *Software*

Whilst off-the-shelf EHR software will need to be purchased, additional software purchases required may also include: project management software; change management software; reporting or analytics software; e-learning applications; operating systems (eg, Windows); disaster recovery systems; service desk systems; anti-virus software [69]; and speech recognition [177]. During procurement,

the interoperability of the software with the EHR and/or legacy systems (e.g., NIMIS, PAS) should be assessed [5], as well as compatibility with the hardware (e.g., data-entry device), need for software security and access to vital records in the event of a failure [178].

(ii) Hardware

Whilst there may be existing hardware in place (e.g., computers, Wi-Fi), this must be assessed for compatibility and capacity with the EHR, and other software purchases [9, 60]. Additional hardware will likely be necessary such as data-entry devices (e.g., laptops), printers, scanners, power sources (e.g., sockets, batteries) and servers [69]. Additionally, the functioning of this hardware is important for reliability (i.e., speed, internet connectivity, bandwidth, power supply) [12, 32, 41, 52, 60, 85, 95, 96, 101]. Several data-entry devices have been discussed in the literature including both stationary and mobile devices. However, literature evaluating and providing recommendations on these devices is limited, likely due to software compatibility varying between vendors, as well as the impact of context and available finance [143]. There are many advantages and disadvantages to using both stationary and mobile devices and it is likely that a combination of both will be utilised by HCPs (Table 5).

Table 5. Summary of the advantages and disadvantages of stationary and mobile devices

	Stationary	Mobile
Data entry devices	Desktop computers and wall-mounted computers	Workstations-on-wheels (WOWs), laptops, tablets and mobile phones
Advantages	• Directly connected to power supply [144, 179] • Directly connected to server[144, 179] • Relatively cheaper to purchase and repair [144, 179] • Can run most software [144, 179] • Lower risk of contamination[144]	• Point-of-care data entry and order requests [143, 148, 180, 181] • Anytime and anywhere access to clinical information including off-site [45, 143, 148, 180, 181] • Enables HCP to spend more time with patients [143, 148, 180, 181] • May require purchase of less devices as they are portable between patients [45, 180] • Can be used to share information with patients and optimise patient engagement [144]
Disadvantages	• Can limit point-of-care data entry and access • Takes up a lot of space or may require adequate wall structure and wiring [95, 144]	• Batteries need to be charged [66, 144, 148, 176, 182, 183] • Loss of connectivity moving through hospital [181] or in remote locations [184] • Risk of contamination [185, 186] • Can be more costly to purchase and repair [144, 179]
Suggested uses	Private or isolation rooms, outpatient clinics and for long narrative clinical notes	Multiple-bed wards, remote locations and for ward rounds and checklist-based assessments

Stationary computers: Two types of stationary computers have been utilised for data entry, desktop computers and wall-mounted computers [143]. Whilst desktop computers are often readily available within an organisation, these may not always be compatible with the EHR [143], they take up a lot of space [95] and unless the stationary computer is within close range of the patient, the end-user has to move away from the patient to input or access data [95, 143]. However, desktop computers are reportedly preferred by HCPs for more-time consuming tasks such as recording assessments [143, 176]. Conversely, wall-mounted computers take up less space and have moveable screens to facilitate sharing of clinical information with the patient [69, 122, 144]. This will however require assessment of the wall structure and wiring capabilities before installation [144].

Mobile devices: Compared to stationary computers, mobile devices can improve workflow efficiency and quality of care with point-of-care data entry and access to information as well as the ability to a easily share the screen with patients [143, 148, 180, 181] (Table 5). Additionally, portability has been considered an important quality attribute of EHR systems [12, 182]. However, internet connectivity has reportedly been an issue when moving these devices as well as battery life, and thus, they need to be tested in every part of the healthcare organisation where they will be utilised and protocols for charging devices need to be in place which are easily followed by staff [183]. Mobile devices discussed in the literature include (1) Workstation-on-wheels (WOWs); (2) Laptops or convertible tablets; (2) Slate tablets; and (4) Mobile phones.

(1) *Workstation-on-wheels (WOW):* A WOW is a computer placed on a mobile cart which runs on a wireless network to provide access to the EHR [148, 180]. These devices are more expensive than stationary PCs (estimated at the cost of three PCs), however they can be shared across areas and thus, less may be required [69, 95]. As well as the benefits of being portable during ward rounds [66, 176], these devices allow the user to carry additional devices or supplies (e.g., medications), and supports point-of-care technology (e.g., bar code medication administration) [144, 179, 181]. Challenges have been met with use of WOWs with studies identifying that other than for medication administration, end-users with access to WOWs often continue to document on paper at point-of-care and transfer the information to the EHR at a later time using stationary desktops [143, 148]. Poor adoption may be attributed to batteries not being charged [66, 144, 148, 176, 182, 183], heavy and bulky carts with sticky or misaligned wheels which are difficult to push, poor connectivity [143, 148], poor ergonomics [148, 180, 183], negative effect on patient communication due to its size [148], unavailable as left in another ward [32], power-save and safety log-offs [148, 183]. Other challenges presented with the use of WOWs include the potential for disease transmission from environmental contamination [185, 186]. Therefore, the number of WOWs required will depend on the physical set-up of the ward, the end-users and type of patients [69]. It should be noted that few recent studies evaluating WOWs were identified and they are becoming more cost-effective and compact with improved battery power [182].

(2) *Laptops or Convertible Tablets:* Most of the literature has focused on tablet PCs in a convertible (i.e., attached keyboard) form rather than on laptops [187]. They are relatively cheaper than WOWs [187], require only one login as it stays with the end-user [188], and are said to allow immediate access to information and have a faster response time than computers [71]. However, they heat up and may not pass safety regulations [69], are susceptible to theft, being misplaced and connection hacking [12, 66, 184, 189], and can be unreliable with connectivity and battery life [143, 190]. As tablets are evolving, some also come with integrated barcode and radio frequency identification (RFID) readers to facilitate point-of-care technologies (i.e., barcode medication administration) [183]

(3) *Slate Tablets:* Whilst similar findings are reported with use of slate tablets, these are usually lighter than convertible tablets [143, 179, 183], easy to clean [183, 188] and facilitate the clinician to retain eye-contact with the patient [143]. Whilst slate tablets are reportedly best used with checklists, such as documenting admissions [143], they also facilitate pen and stylus input, however, this can be difficult-to-use partly due to small screens [69, 143, 176, 179, 182].

(4) *Mobile Phones:* Compatibility and usability of commercially available EHR systems with smaller screens has reportedly been an issue [179, 182]. Additionally there is limited storage on mobile phones and a higher risk of theft [184]. Additionally, as mobile phone use has been discussed for use in the community, there are additional issues such as bandwidth of the network resulting in need to prefetch and download of data [184]. However, some vendors are developing EHRs for mobile phones.

Healthcare organisations often supply both stationary and mobile computing technologies [176] as device suitability depends on discipline, setting, physical layout, user preference and the task (Table 5) [11, 45, 71, 143, 176, 180, 191]. Technical aspects which should be considered when selecting devices include compatibility with EHR software, the ICT infrastructure of the organisation (e.g., power outlets, Wi-Fi, computers) and data security, data quality, and interoperability standards [71, 96]. Devices should be trialled and tested in all the settings they will be used in to ensure usability and reliability [11, 95, 181]. User involvement in these decisions often leads to improved satisfaction and adoption among users [144], as well as avoiding unnecessary time and money spend on unsuitable devices and functions that do not meet the needs of current work practices [12, 148]. Additionally, end-users need to be trained in use of the EHR software on all devices they will be expected to use, as otherwise studies report poor adoption

[176]. It is also recommended that devices are adaptable to meet the needs of different HCPs (e.g., adjustable height; tablet handle) [148, 176, 180, 183] and as healthcare changes (e.g., the addition of a locked cabinet for carrying medication on a WOW) [176, 181]. Other human factors which need to be considered are the impact of different devices on work processes, patient-clinician interactions and interdisciplinary communications [148].

Device cost will also be a determinant in selecting devices and thus, a cost-benefits analysis needs to be considered in the purchase of equipment as well as consideration of what is already available [100, 143]. As these devices are high-touch surfaces, deciding on mobile devices versus stationary devices should consider the setting and risk of disease transmission and environmental contamination, as well as development of policies for cleaning and educating staff on decontamination and disinfection processes [185, 186]. Some cleaning protocols have been developed by organisations such as the Center for Disease Control and Prevention which recommends that noncritical patient care devices be cleaned once-a-day or as needed [192]. However, non-compliance has been reported when this was the responsibility of the end-user compared to housekeeping staff [193] and other research has discussed that the number of contact events should determine the frequency of cleaning rather than a passage of time [185].

Whichever devices are chosen, there needs to be a sufficient numbers of devices, power outlets and chargers available at all times or else time and energy is lost by end-users [32, 41, 85, 95, 96, 101, 143]. There are numerous contextual factors relating to the number of devices required such as type of device, staffing patterns, number of beds and private rooms, and patient populations [143, 148, 176]. This may be the reason that there are minimal recommendations in the literature and variances exist. For example one study discussed a hospital (37 wards) purchasing 150 standard and 100 wall-mounted PCs, 50 COWs, and around 300 infection-control keyboards [69], another study reported a 26-bed ward having seven stationary PCs, six WOWs and two tablets [71], and Cambridge University Hospital with 1,200 hospital beds reported installation of some 6,750 personal computers and 500 laptops, 395 WOWs and 420 tablets [59]. Another study discussed the provision of device-to-patient ratio of 2:1 which allowed for a better state of digital readiness [74]. It has therefore been recommended that determining the numbers of data-entry devices should consider communication with sites who have already set up systems, as well as user involvement on the ground [11, 95], while also balancing accessibility with security [32, 95].

Key Findings for Infrastructure:

1. Hardware and software will need to be purchased and/or updated to ensure a reliable, functioning and accessible EHR to promote patient safety and end-user satisfaction.
2. Data-entry devices need to be compatible with the EHR and other IT infrastructure (e.g., Wi-Fi)
3. A combination of mobile and stationary devices will likely be required for different settings.
4. Adequate connectivity and power sockets and chargers are required across the organisation.

5.4 Regulation, Standards and Policies

Regulations, standards and policies are essential during an EHR implementation to ensure the EHR protects the privacy of patient data and enables interoperability across EHR systems [12, 13, 41]. Lack of consistent national and international standards has been cited as one of the major barriers to interoperability which has limited the development of a fully interoperable EHR which can share information between primary and secondary care settings [5, 41, 49, 50]. Additionally, the increased capacity of an EHR to capture, use and exchange sensitive personal information [135], has led to concerns amongst HCPs and patients regarding the privacy and security of personal health data [9, 11-13, 32, 34, 47, 49-51, 95, 96, 128, 133]. To ensure the security of patient information and address the concerns of stakeholders, data privacy and security policies also need to be in place.

(i) Data Standards

Developing and implementing national and international data standards can improve interoperability between systems and thus, improve patient care [5, 41, 49, 50]. Syntactic (i.e., structural) interoperability is the agreement about the way medical information is imported or exported by the health information systems [194]. To enable syntactic interoperability, the Health Information Quality Authority (HIQA) of Ireland has recommended the adoption of international data standards which have been fully implemented and validated, are open and non-proprietary, and require only minimum adaptation to meet the requirements of the Irish health sector [5]. International standards to facilitate interoperability include [5, 13, 15, 43, 50, 71] :

- International Organisation for Standardization, ISO (www.iso.org)
- European Committee for Standardization, CEN (www.cen.eu)
- International Health Terminology SDO, IHTSDO (www.ihtsdo.org)
- Health Level Seven, HL7 (www.hl7.org)
- Digital Imaging and Communications in Medicine, DICOM (http://medical.nema.org/)
- OpenEHR, (www.openehr.org)
- Integrating the Healthcare Enterprise, IHE (www.ihe.net)

Once the international or national data standards have been identified, all vendors, suppliers and healthcare organisations (including GPs) need to meet these data standards [22]. Financial incentives and penalties have been utilised internationally (e.g., UK, US, Denmark) to ensure all stakeholders employ the established standards [18]. Ensuring all vendors employ the standards in developing their products can also reduce vendor lock-in and dependency, and allows a mixed IT ecosystem to flourish [5, 59].

Semantic interoperability, which is the shared meaning and understanding of clinical data across organisational and geographical boundaries, is also required to enable the sharing of information between clinical information systems [71]. Use of standardised terminologies facilitate semantic interoperability as well as accurate and comprehensive searches [195-197], and CDS software [175, 198, 199]. Several standardised terminologies have been developed internationally but no single terminology has been accepted as a universal standard [200]. In Ireland, HIQA have recommended the use of the Systematized Nomenclature of Medicine - Clinical Terms (SNOMED-CT), which is a clinical reference terminology with thousands of codes which can be utilised to capture all clinical notes including allergies, vitals, past history, family history, symptoms, clinical findings and diagnosis [201]. However,

additional reference terminologies may be utilised alongside this to describe laboratory results (e.g., Logical Observation Identifiers Names and Codes [LOINC]) or medications (e.g., RxNorm) [195, 201, 202]. To reduce time spent searching through thousands of codes for the most appropriate and to capture more granularity and clinical intent of documentation for a specific discipline or speciality, interface terminologies have also been developed (e.g., standardised nursing languages) [202]. Whilst different terminologies can be utilised within an EHR and mapped to one another [203-205], changing terminology within the EHR can be expensive and labour-intensive and thus, it is recommended that decisions regarding terminology use are made before design and development of the EHR interface [206].

(ii) Data Privacy and Security Policies

With the implementation of an EHR, data protection policies need to be developed and employed [13, 32], such as the General Data Protection Regulation (GDPR) which mitigate risks of privacy disclosure by improper authorisation, misuse and abuse [207]. Under such regulations, patients should be informed of how their personal health data will be stored, who will have access to it and how it will be used amongst other rights. Due to the change in how clinical data is stored, accessed and utilised, different models of patient consent have been discussed in the international literature. In Australia for the national implementation of the PHR, they began with an opt-in patient consent model but after poor adoption by citizens, they subsequently changed to an opt-out model [208]. The UK also chose an opt-out consent model for their national PHR [59] and there have been reports by trusts discussing the use of patient consent procedures for each specific data use (e.g., clinical uses and research) [209]. However, introduction of GDPR has eliminated the use of opt-out consent models as they are essentially pre-ticked boxes [210], so other methods of engaging patients in PHRs will be required to promote opt-in to such EHR functions in the future.

Once data privacy policies are in place, security elements and safeguards will be needed in the technology. Although an EHR brings new risks to data breaches, it should be noted that paper-based records were not free of these risks as paper charts could be misplaced and accessed by unauthorised personnel. EHRs provide an opportunity to add safeguards for patient data, such as passwords and role-based access control [132]. Role-based access control can restrict the access to clinical information of a HCP to what is deemed relevant for their role or service [209, 211]. This does however require in depth knowledge of what areas of the EHR each HCP needs to access and/or edit in each healthcare organisation and requires a substantial amount of testing. Other safeguards of the EHR which can be deployed to ensure regulations and policies are followed, include regular monitoring of HCP access [209, 211], login passwords, limited access by end-users to logging onto a single device, limited time before system logs out [148] and restrictions on simultaneous login by more than one HCP on the same device [176]. Finally, as EHRs are at risk of a cyberattack, IT staff need to be able to identify vulnerabilities and potential attacks, as well as to act quickly to stop an attack [212].

Key Findings for Regulation, Standards and Policies:

1. International interoperability standards should be employed where possible, to ensure the consistent format of importing and exporting data by all devices and systems which need to be integrated with the EHR.
2. Standardised terminologies should be utilised to ensure a common language which has a common and consistent meaning and value across organisations.
3. Technical security elements within the EHR are required to prevent unauthorised access to patient data in line with data protection policies and regulations.

5.5 Adaptability

To ensure the EHR meets the needs of the end-users and the work practices of the organisation, there must be a sufficient degree of flexibility in the software to enable adaptation or customisation [32, 41, 47, 49]. Although this factor was not as prevalent as others across the available literature, this was likely due the literature focusing on HCPs as opposed to software developers and IT staff. In Germany, a major challenge to the implementation of an EHR was the insufficient attention given to the further development and adaptability of the EHR [19]. Whilst an EHR system might be successful in one healthcare organisation, adaptations will likely be required for implementation in another organisation due to variances in workflows and roles *(See Section 3.6 Workflows)*. Although end-user involvement during the development and design will limit the need for future adaptations [41], due to the nature of healthcare, it is likely that a healthcare organisation will need to modify existing features and add new features as the external health system changes [41, 71]. Other reasons the EHR system may need to be adapted include facilitating interoperability with legacy or new systems [33, 41] and reducing 'alert fatigue' [33, 213]. Whilst safety alerts in the EHR can help improve patient safety, where HCPs are exposed to a large number of alerts, they can become desensitised to them which limits their effectiveness and negatively affects EHR usability. One method of reducing alert fatigue discussed in the literature, was to adapt the alerts designed by vendors [213]. Overall, customising the EHR product to meet the needs of end-users improves the adoption rate, usability, user satisfaction and patient safety [32, 33, 41].

Whilst the vendor must be willing to adapt their product during the design phase to meet the needs of the specific healthcare organisation, they also need to be open to sharing data to enable adaptations of the EHR to occur post implementation [32, 33, 49]. However, the healthcare organisation also needs to have access to a workforce with the IT skills to adapt the EHR who also understand the clinical workflows of the organisation [33, 104]. According to the literature, this has made implementations in smaller practices more difficult as they do not have access to the needed IT knowledge and skills [49]. However, due to the sometimes restrictive nature of technology, end-users will also need to adapt their work processes to the software, as opposed to always adapting the technology to the end-user [32, 47]. The development and integration of standards to ensure semantic and syntactic interoperability will reduce the level of EHR product customisation required [33], however it is unlikely that the workflows of every hospital and primary care centre will be able to be standardised nationally and therefore, product adaptability will remain critical. Overall, the purchase of flexible products where possible and investment in an IT workforce staff who have the ability to customise the product will help avoid a dependent and costly relationship with the vendor [45].

Key Findings for Adaptability:

1. Adaptability refers to software flexibility which enables product customisation to meet the needs of end-users and the healthcare organisation.
2. Adaptations will be needed at time of EHR development and post implementation to optimise the EHR and adapt to an evolving health system.
3. To facilitate software adaptability, vendors need to be open to sharing data and organisations need access to a skilled workforce who can adapt the EHR and understand clinical workflows.

5.6 Testing

Testing of the EHR is essential to ensure patient safety and a usable and effective EHR for end-users, as well as limiting the need for future adaptations of the EHR which are costly and require additional training [214-216]. Although testing is an extremely important aspect of EHR development, this factor appeared to be underestimated as it was not highlighted in the identified literature reviews as a factor for EHR success. However, testing is required to ensure usability, interoperability and the selection of suitable and sufficient infrastructure. According to the Office of the National Coordinator of Health Information Technology, every EHR system must be comprehensively tested to ensure that data, tables and files have been loaded properly, data collected are processed and stored correctly, interfaces work, workflows have been adjusted appropriately, alerts fire correctly, and reports are generated accurately and completely [217]. A high level of quality testing has also been recommended by the EU ANTILOPE project once a system meets the specifications for interoperability [173]. Whilst vendors should be engaged in performing these tests, the organisation needs to have its own staff involved in testing, which should include HCP representatives [215, 217]. Therefore, development and resourcing of a configuration and testing team will be needed to build and test the EHR system and this team may include product specialists, software developers, test managers, test script manager and testers [69]. Additional resourcing required will include physical space for testing and development of test patients and test accounts [214].

Software testing is a multistep process that encompasses a wide variety of techniques and strategies (Fig. 3) [214, 217]. Initially, the individual function will need to be tested within the production environment, followed by testing the function as part of the entire system to assess its effects on workflows and downstream processes within the EHR [33, 71, 124]. Test scenarios need to be developed and should focus on tasks considered to be high risk as well as those performed regularly by HCPs [215]. The system should then be tested in a simulated environment prior to testing in a live environment (i.e., clinical setting) using all the selected data-entry devices (e.g., tablets) [214, 217]. Finally, usability testing with end-users throughout the process is required to access their satisfaction and acceptance [33, 97].

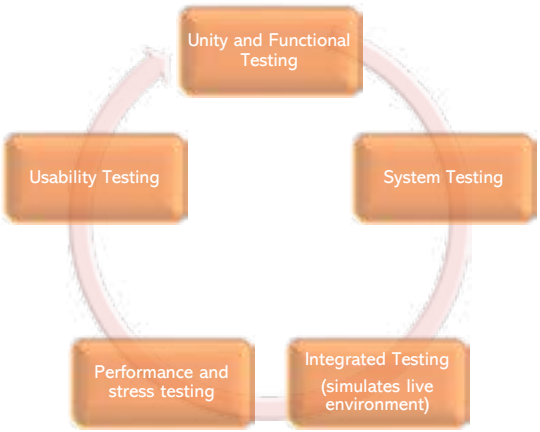


Figure 3. Testing processes identified in the literature

It has been reported that many certification testing processes lack rigor especially where all testing has occurred the production or testing environment [215]. Testing the EHR in the real-world environment is now recognised as extremely important as it assesses the system performance under stress which may include a high volume of traffic which is difficult to merely simulate and enables access to all the other interfaces which the EHR will need interact with which may not be present in the testing environment (e.g., barcode scanners, printers) [215]. Additionally, it has been identified that many errors do not appear in a simulated clinical environment [97, 214, 215, 217]. However, where test scenarios are utilised in real-world environments, test patients must be clearly defined e.g., including "ZZZ," and "training" or "testing" as part of the name, or using a different colour for test patients), testers should

be given unique distinctive usernames rather than their real account, and reports and data extracts should be configured to exclude test patients [214].

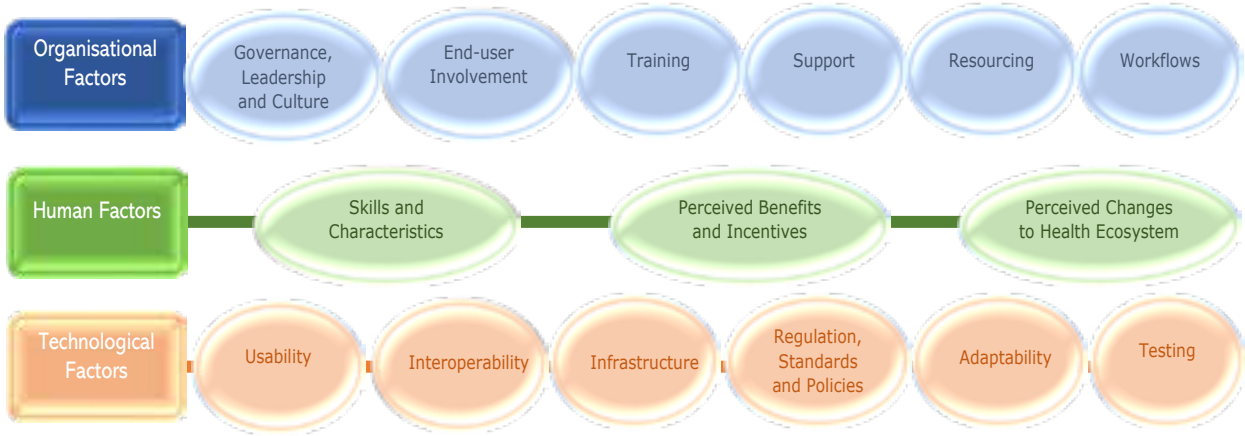
Finally, validation criteria needs to be set prior to testing [97] and may include established standards such as the Safety Assurance Factors for EHR Resilience (SAFER) guides and System Usability Scale (SUS) [9, 33, 71, 90]. Methods of testing may vary depending on the stage of EHR implementation for example, during the development stage usability is often testing using formative evaluations such as qualitative methods (e.g., focus groups, observations) to define user needs and inform improvements compared to summative testing which uses more one-on-one testing during the pilot stage [97, 218, 219]. Just as adaptations to the EHR remain ongoing post implementation, the comprehensive testing process must also continue for each adaptation made [214, 215]. End-users can usually request changes to the EHR via the change request board or required changes may be identified by workflow analysis post Go Live [45]. However, each change to the EHR should be considered slow and incremental and follow a defined process (Fig. 3) followed by deployment with real patients with close monitoring [33, 50, 214]. End-users should be aware that there will be a learning curve and adaptations to the software will be required even after Go Live and these can be made upon request [101].

Key Findings for Testing:

1. Testing is a multi-step process which requires heavy resourcing in terms of time, finance and staffing.
2. Testing in real-world environments is very important in order to identify potential safety risks and inefficiencies whilst the system is 'under stress' and interacting with other infrastructure not available in the testing environment (e.g., scanners).
3. Ongoing testing will be required for each adaptation made to optimise the EHR.

6 Conclusion

Based on the literature identified and valuable insights of the Advisory Group, fifteen key factors which are important for a successful EHR implementation were identified under the categories of Organisational, Human and Technological Factors:



Each of the key success factors are interlinked with another factor, for example the quality of training as well as the usability of the EHR will influence the skills and competency of the individual end-user, and therefore, a successful implementation requires consideration of each factor. Future EHR implementations need to learn from the successes and even more importantly, the failures experienced during previous EHR implementations in relation to these factors. Otherwise, implementations risk repeating the same errors and creating the same challenges which could have been pre-empted. Although this report provides an overview of the available literature related to each of these success factors, a more in-depth review of the literature surrounding each of these factors is recommended. Additionally, further learnings can be gained by speaking directly with healthcare organisations with live EHRs. Overall, although needs will vary depending on the size and type healthcare setting, each of these factors will be relevant and important to the success of each EHR implementation in Ireland.

References

1. eHealth Ireland. Electronic Health Record, 2019 [Available from: https://www.ehealthireland.ie/Strategic-Programmes/Electronic-Health-Record-EHR-/.
2. Gartner. Healthcare EHR and Digital Care Delivery Optimization Primer for 2019. 2019.
3. Health Service Executive. National eHealth Strategy. Ireland: Dublin; 2015.
4. Department of Health. Sláintecare Implementation Strategy. Ireland: Dublin; 2017.
5. Health Information and Quality Authority (HIQA). Developing National eHealth Interoperability Standards for Ireland: A Consultation Document. Dublin: Ireland; 2011.
6. International Organization for Standardization (ISO). International Organization for Standardization ISO/TR 20514:2005. 2005.
7. Warraich HJ, Califf RM, Krumholz HM. The digital transformation of medicine can revitalize the patient-clinician relationship. npj Digital Medicine. 2018;1(1).
8. Carnicero J, Rojas D. Lessons Learned from Implementation of Information and Communication Technologies in Spain's Healthcare Services: Issues and Opportunities. Appl Clin Inform. 2010;1(4):363-76.
9. Sligo J, Gauld R, Roberts V, Villa L. A literature review for large-scale health information system project planning, implementation and evaluation. Int J Med Inform. 2017;97:86-97.
10. Castillo V, Martínez-García A, Pulido J. A knowledge-based taxonomy of critical factors for adopting electronic health record systems by physicians: a systematic literature review. BMC Medical Informatics and Decision Making. 2010;10(60).
11. Ajami S, Bagheri-Tadi T. Barriers for Adopting Electronic Health Records (EHRs) by Physicians. Acta Inform Med. 2013;21(2):129-34.
12. Nguyen L, Bellucci E, Nguyen LT. Electronic health records implementation: an evaluation of information system impact and contingency factors. Int J Med Inform. 2014;83(11):779-96.
13. O'Donnell A, Kaner E, Shaw C, Haighton C. Primary care physicians' attitudes to the adoption of electronic medical records: a systematic review and evidence synthesis using the clinical adoption framework. BMC Med Inform Decis Mak. 2018;18(1):101.
14. eHealth Network. Refined eHealth European Interoperability Framework. Brussels: Sweden; 2015.
15. Kouroubali A, Katehakis DG. The New European Interoperability Framework as a Facilitator of Digital Transformation for Citizen Empowerment. J Biomed Inform. 2019:103166.
16. Fragidis LL, Chatzoglou PD. Implementation of a nationwide electronic health record (EHR). Int J Health Care Qual Assur. 2018;31(2):116-30.
17. Moullin JC, Sabater-Hernandez D, Fernandez-Llimos F, Benrimoj SI. A systematic review of implementation frameworks of innovations in healthcare and resulting generic implementation framework. Health Res Policy Syst. 2015;13:16.
18. Lluch M. Healthcare professionals' organisational barriers to health information technologies-a literature review. Int J Med Inform. 2011;80(12):849-62.
19. Deutsch E, Duftschmid G, Dorda W. Critical areas of national electronic health record programs-is our focus correct? Int J Med Inform. 2010;79(3):211-22.
20. Campion-Awwad O, Hayton A, Smith L, Vuaran M. The National Programme for IT in the NHS A Case History. University of Cambridge; 2014.
21. eHealth Ireland. eHealth Ireland 2019 [Available from: https://www.ehealthireland.ie/.
22. HSE. National Electronic Health Record: Vision and Direction. Dublin: Ireland; 2015.
23. eHealth Ireland. Shared Record Programme: Business Case Summary. 2017.
24. Roehrs A, da Costa CA, Righi RD, de Oliveira KS. Personal Health Records: A Systematic Literature Review. Journal of medical Internet research. 2017;19(1):e13.
25. Ammenwerth E, Schnell-Inderst P, Hoerbst A. The impact of electronic patient portals on patient care: a systematic review of controlled trials. Journal of medical Internet research. 2012;14(6):e162.

26. Bouayad L, Ialynytchev A, Padmanabhan B. Patient Health Record Systems Scope and Functionalities: Literature Review and Future Directions. Journal of medical Internet research. 2017;19(11):e388.
27. eHealth Ireland. Maternal & Newborn Clinical Management System 2019 [Available from: https://www.ehealthireland.ie/Strategic-Programmes/MNCMS/.
28. Adler-Milstein J, Holmgren AJ, Kralovec P, Worzala C, Searcy T, Patel V. Electronic health record adoption in US hospitals: the emergence of a digital "advanced use" divide. J Am Med Inform Assoc. 2017;24(6):1142-8.
29. Gold M, McLaughlin C. Assessing HITECH Implementation and Lessons: 5 Years Later. The Milbank Quarterly. 2016;94(3):654-87.
30. Jacob J. On the Road to Interoperability, Public and Private OrganizationsWork to Connect Health Care Data. JAMA 2015;314(2):1213-5.
31. Aromataris E, Fernandez R, Godfrey CM, Holly C, Khalil H, Tungpunkom P. Summarizing systematic reviews: methodological development, conduct and reporting of an umbrella review approach. International journal of evidence-based healthcare. 2015;13(3):132-40.
32. Boonstra A, Versluis A, Vos J. Implementing electronic health records in hospitals: a systematic literature review. BMC Health Services Research 2014;14:370.
33. Ratwani R, Fairbanks T, Savage E, Adams K, Wittie M, Boone E, et al. Mind the Gap. A systematic review to identify usability and safety challenges and practices during electronic health record implementation. Appl Clin Inform. 2016;7(4):1069-87.
34. Ludwick DA, Doucette J. Adopting electronic medical records in primary care: lessons learned from health information systems implementation experience in seven countries. Int J Med Inform. 2009;78(1):22-31.
35. Powell BJ, Proctor EK, Glass JE. A Systematic Review of Strategies for Implementing Empirically Supported Mental Health Interventions. Res Soc Work Pract. 2014;24(2):192-212.
36. Montori VM, Wilczynski NL, Morgan D, Haynes RB, Hedges T. Optimal search strategies for retrieving systematic reviews from Medline: analytical survey. BMJ. 2005;330(7482):68.
37. HIQA. National Standard on information requirements for a national electronic patient summary. 2018.
38. Graneheim UH, Lundman B. Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. Nurse Educ Today. 2004;24(2):105-12.
39. Cresswell K, Sheikh A. Organizational issues in the implementation and adoption of health information technology innovations: an interpretative review. Int J Med Inform. 2013;82(5):e73-86.
40. Paré G, Sicotte C, Jaana M, Girouard D. Prioritizing the risk factors influencing the success of clinical information system projects. A Delphi study in Canada. Methods Inf Med. 2008;47(3):251-9.
41. Ross J, Stevenson F, Lau R, Murray E. Factors that influence the implementation of e-health: a systematic review of systematic reviews (an update). Implementation Science. 2016;11(1).
42. Justinia T. The UK's National Programme for IT: Why was it dismantled? Health Serv Manage Res. 2017;30(1):2-9.
43. Nguyen T, Kaija S, Tapanainen T, Ishmatova D. A Review of Health Information Technology Implementation Success Factors: Importance of Regulation and Finance. 2014 47th Hawaii International Conference on System Sciences2014. p. 2693-705.
44. The Office of the National Coordinator for Health Information Technology. Creating a Leadership Team for Successful Electronic Health Record (EHR) Implementation. 2016.
45. The King's Fund. Digital change in health and social care. England; 2018.
46. Scott JT, Rundall, T. G., Vogt, T. M., & Hsu, J. . Kaiser Permanente's experience of implementing an electronic medical record: A qualitative study. British Medical Journal,. 2005;331:1313-16.
47. Kruse CS, Kristof C, Jones B, Mitchell E, Martinez A. Barriers to Electronic Health Record Adoption: a Systematic Literature Review. J Med Syst. 2016;40(12):252.
48. Coiera E. Building a National Health IT System from the middle out. J Am Med Inform Assoc. 2009;16(3):271-3.

49. Boonstra A, Broekhuis M. Barriers to the acceptance of electronic medical records by physicians from systematic review to taxonomy and interventions. BMC Health Serv Res. 2010;10:231.
50. Police RL, Foster T, Wong KS. Adoption and use of health information technology in physician practice organisations: systematic review. Informatics in primary care. 2010;18(4):245-58.
51. de Grood C, Raissi A, Kwon Y, Santana MJ. Adoption of e-health technology by physicians: a scoping review. J Multidiscip Healthc. 2016;9:335-44.
52. Fritz F, Tilahun B, Dugas M. Success criteria for electronic medical record implementations in low-resource settings: a systematic review. J Am Med Inform Assoc. 2015;22(2):479-88.
53. Burnel P. The introduction of electronic medical records in France: More progress during the second attempt. Health Policy. 2018;122(9):937-40.
54. Eason K, Dent M, Waterson P, Tutt D, Thornett A. Bottom-up and middle-out approaches to electronic patient information systems: a focus on healthcare pathways. Informatics in primary care. 2012;20:51-6.
55. Cresswell K, Morrison Z, Crowe S, Robertson A, Sheikh A. Anything but engaged: user involvement in the context of a national electronic health record implementation. Journal of Innovation in Health Informatics. 2011;19(4):191-206.
56. Dutchhealthcare. The rise and fall of the National EHR initiative in the Netherlands.; 2011.
57. Kannry J, Sengstack P, Thyvalikakath TP, Poikonen J, Middleton B, Payne T, et al. The Chief Clinical Informatics Officer (CCIO): AMIA Task Force Report on CCIO Knowledge, Education, and Skillset Requirements. Appl Clin Inform. 2016;7(1):143-76.
58. Sridharan S, Priestman W, Sebire NJ. Chief Information Officer team evolution in university hospitals: interaction of the three 'C's (CIO, CCIO, CRIO). J Innov Health Inform. 2018;25(2):88-91.
59. Wachter R. Making IT Work: Harnessing the Power of Health Information Technology to Improve Care in England: Report of the National Advisory Group on Health Information Technology in England. 2016.
60. Topol E. The Topol Review: Preparing the healthcare workforce to deliver the digital future. NHS: England; 2019.
61. Maguire D, Evans H, Honeyman M, Omojomolo D. Digital change in health and social care. The King's Fund; 2018.
62. Shachak A, Barnsley J, Montgomery C, Tu K, Jadad A, Lemieux-Charles L. End-user support for a primary care electronic medical record: a qualitative case study of a vendor's perspective. Informatics in primary care. 2012;20:185–96.
63. Castillo AF, Sirbu M, Davis AL. Vendor of choice and the effectiveness of policies to promote health information exchange. BMC Health Services Research. 2018;18(1):405.
64. Ford E, Menachemi N, Huerta T, Yu F. Hospital IT adoption strategies associated with implementation success: Implications for achieving meaningful use. Journal of Healthcare Management. 2010;55(3):175.
65. Metcalf-Rinaldo O, Jensen S. Learnings from the implementation of Epic Benefits, issues, causes and recommendations. Copenhagen: Denmark; 2016.
66. Clarke A, Adamson J, Sheard L, Cairns P, Watt I, Wright J. Implementing electronic patient record systems (EPRs) into England's acute, mental health and community care trusts: a mixed methods study. BMC Med Inform Decis Mak. 2015;15:85.
67. Stevens L. Three years on from Cambridge's Epic big bang go-live. Digital Health. 2017.
68. Wang T, Biedermann S. Solve the puzzle of electronic health record implementation budgeting. Health Care Manag (Frederick). 2013;32(1):43-8.
69. Slight SP, Quinn C, Avery AJ, Bates DW, Sheikh A. A qualitative study identifying the cost categories associated with electronic health record implementation in the UK. J Am Med Inform Assoc. 2014;21(e2):e226-31.
70. Takian A. Envisioning Electronic Health Record Systems as Change Management: The Experience of an English Hospital Joining the National Programme for Information Technology. Quality of Life through Quality of Information. 2012:901-5.

71. Ben-Zion R, Pliskin N, Fink L. Critical Success Factors for Adoption of Electronic Health Record Systems: Literature Review and Prescriptive Analysis. Information Systems Management. 2014;31(4):296-312.
72. HIMSS. Measuring Success Achieving Metrics 2019 [Available from: https://www.himss.org/measuring-success-achieving-metrics.
73. National Learning Consortium. Change Management in EHR Implementation. 2013.
74. Gunja N, Dunlop I, Vaghasiya M, Kuan K, Poon S. Patient-centric implementation of an electronic medication management system at a tertiary hospital in Western Sydney. J Innov Health Inform. 2018;25(3):169-75.
75. Diggin B, Green D, Evans J, Smoot J, Broun J, Grant M, et al. EMR Implementation – Big Bang or Phased Approach? VitroSoftware. 2016.
76. Weathers A, Esper G. How to select and implement an electronic health record in a neurology practice. Neurology: Clinical Practice. 2013:141-8.
77. Karnas J, Robles J. Implementing the electronic medical record: Big Bang or phased rollout? Creative nursing. 2007;13(2):13-4.
78. Walker J, Bieber E, Richards F. Implementing an electronic health record system. New York Springer-Verlag; 2006.
79. Johnson KB, Ehrenfeld JM. An EPIC Switch: Preparing for an Electronic Health Record Transition at Vanderbilt University Medical Center. J Med Syst. 2017;42(1):6.
80. Digital Health. Special Report: Electronic Document Management 2019 [Available from: https://www.digitalhealth.net/2018/05/special-report-electronic-document-management-5/.
81. Health Service Executive (HSE). Health Service Executive Code of Practice for Healthcare Records Management. 2010.
82. Laerum H, Karlsen TH, Faxvaag A. Effects of scanning and eliminating paper-based medical records on hospital physicians' clinical work practice. J Am Med Inform Assoc. 2003;10(6):588-95.
83. Gill R, Borycki EM. The Use of Case Studies in Systems Implementations Within Health Care Settings: A Scoping Review. Studies in health technology and informatics. 2017;234:142-9.
84. McIntire D, Clark T. Essential Steps in Super User Education for Ambulatory Clinic Nurses. Urologic Nursing 2009;29(5).
85. Whittaker AA, Aufdenkamp M, Tinley S. Barriers and facilitators to electronic documentation in a rural hospital. J Nurs Scholarsh. 2009;41(3):293-300.
86. Halbesleben J, Wakefield D, Ward M, Brokel J, Crandall D. The Relationship Between Super Users'Attitudes and Employee Experiences With Clinical Information Systems. Medical Care Research and Review. 2009;66(1):82-96.
87. Llewellyn S, Procter R, Harvey G, Maniatopoulos G, Boyd A. Facilitating technology adoption in the NHS: negotiating the organisational and policy context - a qualitative study. Health Services and Delivery Research. 2014.
88. Quinlan M. Implementing change in healthcare – lessons in best practice from the movement towards integrated care in the US. . 2016.
89. Ross J, Stevenson F, Lau R, Murray E. Factors that influence the implementation of e-health: a systematic review of systematic reviews (an update). Implement Sci. 2016;11(1):146.
90. U.D.o. Health, H. Services. Health information technology: standards, implementation specifications, and certification criteria for electronic health record technology, 2014 edition; Revisions to the permanent certification program for health information technology. Fed Regist. 2012;77:1-130.
91. Greenhalgh T, Hinder S, Stramer K, Bratan T, Russell J. Adoption, non-adoption, and abandonment of a personal electronic health record: case study of HealthSpace. BMJ. 2010;341:c5814.
92. Ingebrigtsen T, Georgiou A, Clay-Williams R, Magrabi F, Hordern A, Prgomet M, et al. The impact of clinical leadership on health information technology adoption: systematic review. Int J Med Inform. 2014;83(6):393-405.

93. Stephens G, Mitchell D. Patient Engagement in the development of a National Electronic Health Record. International Journal of Integrated Care. 2017;17(5).
94. Pantaleoni JL, Stevens LA, Mailes ES, Goad BA, Longhurst CA. Successful physician training program for large scale EMR implementation. Appl Clin Inform. 2015;6(1):80-95.
95. Strudwick G, Eyasu T. Electronic health record use by nurses in mental health settings: a literature review. Arch Psychiatr Nurs. 2015;29(4):238-41.
96. Gesulga J, Berjame A, Moquiala K, Galido A. Barriers to Electronic Health Record System Implementation and Information Systems Resources: A Structured Review. Procedia Computer Science. 2017;124:544-51.
97. HIMSS. Defining and Testing EMR Usability: Principles and Proposed Methods of EMR Usability Evaluation and Rating. 2009.
98. Yuan CT, Bradley EH, Nembhard IM. A mixed methods study of how clinician 'super users' influence others during the implementation of electronic health records. BMC Med Inform Decis Mak. 2015;15:26.
99. Shachak A, Dow R, Barnsley J, Tu K, Domb S, Jadad AR, et al. User Manuals for a Primary Care Electronic Medical Record System: A Mixed-Methods Study of User- and Vendor-Generated Documents. IEEE Transactions on Professional Communication. 2013;56(3).
100. Mathieson S. Does Cambridge University Hospital's Epic project indicate NHS lacks capacity? Computer Weekly. 2015.
101. Rantz MJ, Alexander G, Galambos C, Flesner MK, Vogelsmeier A, Hicks L, et al. The use of bedside electronic medical record to improve quality of care in nursing facilities: a qualitative analysis. Comput Inform Nurs. 2011;29(3):149-56.
102. KLAS. Successful users' keys to EHR satisfaction: Impact report. UK; 2019.
103. Amatayakul M. Why workflow redesign alone is not enough for EHR success. Healthcare Financial Management. 2011;65(3):130.
104. Shachak A, Montgomery C, Dow R, Barnsley J, Tu K, Jadad AR, et al. End-user support for primary care electronic medical records: a qualitative case study of users' needs, expectations and realities. Health Syst (Basingstoke). 2013;2(3):198-212.
105. Alkureishi M, Lee WW, Webb S, Arora V. Integrating Patient-Centered Electronic Health Record Communication Training into Resident Onboarding: Curriculum Development and Post-Implementation Survey Among Housestaff (Preprint)2017.
106. HCI Group. 2016. [cited 2019]. Available from: http://blog.thehcigroup.com/go-live-support-training-and-super-user-support.
107. UNC Health Care. EPIC@UNC: Super user responsbilities 2018 [Available from: http://news.unchealthcare.org/epic/training/super-user-responsibilities.
108. Shea CM, Reiter KL, Weaver MA, Albritton J. Quality improvement teams, super-users, and nurse champions: a recipe for meaningful use? J Am Med Inform Assoc. 2016;23(6):1195-8.
109. Bloch M, Blumberg S, Laartz J. Delivering large-scale IT projects on time, on budget, and on value. 2012.
110. Jarvis C. Investigate Funding Alternatives to Support Successful EHR Implementation. Medical Practice Management 2009:335-8.
111. Ahmadi M, Aslani N. Capabilities and Advantages of Cloud Computing in the Implementation of Electronic Health Record. Acta Inform Med. 2018;26(1):24-8.
112. Liu V, Haq N, Chan I, Hoberman B. Inpatient Electronic Health Record Maintenance From 2010 to 2015. The American Journal of Managed Care. 2019;25(1):18-21.
113. Meyer G, Britton O, Gross D. Seven Challenges and Seven Solutions for Large-Scale EHR Implementations. NEJM Catalyst. 2018.
114. Schweitzer M, Lasierra N, Hoerbst A. Requirements for Workflow-Based EHR Systems – Results of a Qualitative Study. Health Informatics Meets eHealth. 2016.

115. Militello LG, Arbuckle NB, Saleem JJ, Patterson E, Flanagan M, Haggstrom D, et al. Sources of variation in primary care clinical workflow: implications for the design of cognitive support. Health Informatics J. 2014;20(1):35-49.
116. Waegemann C. What can we learn from EHR developments? International Journal of Computer Assisted Radiology and Surgery. 2016;11(1):SUPPL. 1 (S156 - S7).
117. HIMSS. Health IT 101: Workflow 2019 [Available from: https://www.himss.org/workflow.
118. Russ AL, Saleem JJ, Justice CF, Woodward-Hagg H, Woodbridge PA, Doebbeling BN. Electronic health information in use: Characteristics that support employee workflow and patient care. Health Informatics J. 2010;16(4):287-305.
119. Saleem JJ, Flanagan ME, Russ AL, McMullen CK, Elli L, Russell SA, et al. You and me and the computer makes three: variations in exam room use of the electronic health record. J Am Med Inform Assoc. 2014;21(e1):e147-51.
120. Fisher AM, Herbert MI, Douglas GP. Understanding the dispensary workflow at the Birmingham Free Clinic: a proposed framework for an informatics intervention. BMC Health Serv Res. 2016;16:69.
121. Baxter SL, Gali HE, Huang AE, Millen M, El-Kareh R, Nudleman E, et al. Time requirements of paper-based clinical workflows and after-hours documentation in a multi-specialty academic ophthalmology practice. Am J Ophthalmol. 2019.
122. Weiler DT, Satterly T, Rehman SU, Nussbaum MA, Chumbler NR, Fischer GM, et al. Ambulatory Clinic Exam Room Design with respect to Computing Devices: A Laboratory Simulation Study. IISE Trans Occup Ergon Hum Factors. 2018;6(3-4):165-77.
123. Parent C. How EHRs can give time back to docs. Health Management Technology. 2017.
124. Kelley TF, Brandon DH, Docherty SL. Electronic nursing documentation as a strategy to improve quality of patient care. J Nurs Scholarsh. 2011;43(2):154-62.
125. Meade B, Buckley D, Boland M. What Factors Affect the Use of Electronic Patient Records by Irish GPs? International Journal of Medical Informatics 2009;78(8):551-8.
126. Williams DC, Warren RW, Ebeling M, Andrews AL, Teufel Ii RJ. Physician Use of Electronic Health Records: Survey Study Assessing Factors Associated With Provider Reported Satisfaction and Perceived Patient Impact. JMIR medical informatics. 2019;7(2):e10949-e.
127. Healthcare Information and Management Systems Society (HIMSS). What is EHR Usability: EHR Usability 101 2019 [Available from: https://www.himss.org/what-ehr-usability.
128. McGinn CA, Grenier S, Duplantie J, Shaw N, Sicotte C, Mathieu L, et al. Comparison of user groups' perspectives of barriers and facilitators to implementing electronic health records: a systematic review. BMC Med. 2011;9:46.
129. Gagnon MP, Desmartis M, Labrecque M, Car J, Pagliari C, Pluye P, et al. Systematic review of factors influencing the adoption of information and communication technologies by healthcare professionals. J Med Syst. 2012;36(1):241-77.
130. Corbridge R, O'Loughlin M, Quinlan M, Rooney L, McGovern M. Health in the Digital Society: DHSS Task Force 4- Digital Transformation. 2017.
131. Hendy J, Reeves B, Fulop N, Hutchings A, Masseria C. Challenges to implementing the national programme for information technology (NPfIT): a qualitative study. . BMJ 2005;331:331–6.
132. Afshar M, Samet S, Hu T. An Attribute Based Access Control Framework for Healthcare System. Journal of Physics: Conference Series. 2018;933.
133. O'Malley C, Berry D, Sharp M. Attitudes of Health Professionals to Electronic Data Sharing within an Integrated Care Electronic Health Record (ICEHR). 15th Annual Conference of The Health Informatics Society of Ireland; Stillorgan, Dublin2010.
134. International Organization for Standardization (ISO). Health informatics - Audit trails for electronic health records (ISO 27789:2013). 2013.
135. International Organization for Standardization (ISO). ISO/TS 17975:2015(en): Health informatics — Principles and data requirements for consent in the Collection, Use or Disclosure of personal health information. 2015.

136. Shepard A. Disaster Recovery and the Electronic Health Record. Nurs Adm Q. 2017;41(2):187-9.
137. Kazmi Z. Effects of exam room EHR use on doctor-patient communication: a systematic literature review. Informatics in primary care. 2013;21(1):30-9.
138. Crampton NH, Reis S, Shachak A. Computers in the clinical encounter: a scoping review and thematic analysis. J Am Med Inform Assoc. 2016;23(3):654-65.
139. Alkureishi MA, Lee WW, Lyons M, Press VG, Imam S, Nkansah-Amankra A, et al. Impact of Electronic Medical Record Use on the Patient-Doctor Relationship and Communication: A Systematic Review. Journal of general internal medicine. 2016;31(5):548-60.
140. Shachak A, Reis S. The impact of electronic medical records on patient-doctor communication during consultation: a narrative literature review. J Eval Clin Pract. 2009;15(4):641-9.
141. Shultz CG, Holmstrom HL. The Use of Medical Scribes in Health Care Settings: A Systematic Review and Future Directions. The Journal of the American Board of Family Medicine. 2015;28(3):371-81.
142. KLAS. EHR MASTERY: SCRIBES AND VOICE RECOGNITION NOT THE ANSWER (YET): IMPACT REPORT. Scotland; 2018.
143. Carlson E, Catrambone C, Oder K, Nauseda S, Fogg L, Garcia B, et al. Point-of-care technology supports bedside documentation. J Nurs Adm. 2010;40(9):360-5.
144. Cuda D. White paper: Finding balance in medical workstations: Mobile Carts VS. Wallmounts. 2013.
145. Patel MR, Vichich J, Lang I, Lin J, Zheng K. Developing an evidence base of best practices for integrating computerized systems into the exam room: a systematic review. J Am Med Inform Assoc. 2017;24(e1):e207-e15.
146. Antoun J, Hamadeh G, Romani M. Effect of computer use on physician-patient communication using interviews: A patient perspective. Int J Med Inform. 2019;125:91-5.
147. European Commission. The European Commission's High Level Expert Group on Artificial Intelligence. Brussels; 2018.
148. Tang C, Carpendale S. Evaluating the Deployment of a Mobile Technology in a Hospital Ward. Proceedings of the 2008 ACM conference on Computer supported cooperative work; San Diego, CA, USA2008. p. 205-14.
149. Khairat S, Marc D, Crosby W, Al Sanousi A. Reasons For Physicians Not Adopting Clinical Decision Support Systems: Critical Analysis. JMIR Med Inform. 2018;6(2):e24.
150. KLAS. Improving the EHR expereince through personalization: Impact report. UK; 2018.
151. Howe J, Adams K, Hettinger Z, Ratwani R. Electronic Health Record Usability Issues and Potential Contribution to Patient Harm. JAMA 2018;319(12):1276-8.
152. Hodgson T, Magrabi F, Coiera E. Evaluating the usability of speech recognition to create clinical documentation using a commercial electronic health record. Int J Med Inform. 2018;113:38-42.
153. Hine N, Petersen F, Pluke M, Sund T, editors. Standardization work on personalized eHealth systems. 30th Annual International IEEE EMBS Conference 2008; Vancouver, British Columbia, Canada.
154. Rosenbloom ST, Denny JC, Xu H, Lorenzi N, Stead WW, Johnson KB. Data from clinical notes: a perspective on the tension between structure and flexible documentation. J Am Med Inform Assoc. 2011;18(2):181-6.
155. Johnson SB, Bakken S, Dine D, Hyun S, Mendonca E, Morrison F, et al. An electronic health record based on structured narrative. J Am Med Inform Assoc. 2008;15(1):54-64.
156. Helgheim BI, Maia R, Ferreira JC, Martins AL. Merging Data Diversity of Clinical Medical Records to Improve Effectiveness. Int J Environ Res Public Health. 2019;16(5).
157. Linder JA, Schnipper JL, Middleton B. Method of electronic health record documentation and quality of primary care. J Am Med Inform Assoc. 2012;19(6):1019-24.
158. Healthcare Information and Management Systems Society (HIMSS). HIMSS Transforming health through information and technology: What is Interoperability? 2019 [Available from: https://www.himss.org/library/interoperability-standards/what-is-interoperability.

159. Zheng X, Sun S, Mukkamala RR, Vatrapu R, Ordieres-Mere J. Accelerating Health Data Sharing: A Solution Based on the Internet of Things and Distributed Ledger Technologies. Journal of medical Internet research. 2019;21(6):e13583.
160. Strudwick G, McGillis Hall L. Nurse acceptance of electronic health record technology: a literature review. Journal of Research in Nursing. 2015;20(7):596-607.
161. Gunter TD, Terry NP. The emergence of national electronic health record architectures in the United States and Australia: models, costs, and questions. Journal of medical Internet research. 2005;7(1):e3.
162. Castañeda M. Connecting Devices and Data on the Healthcare Network. Biomedical Instrumentation & Technology. 2010:18-25.
163. Kruse CS, Kothman K, Anerobi K, Abanaka L. Adoption Factors of the Electronic Health Record: A Systematic Review. JMIR Med Inform. 2016;4(2):e19.
164. Plastiras P, O'Sullivan D. Exchanging personal health data with electronic health records: A standardized information model for patient generated health data and observations of daily living. Int J Med Inform. 2018;120:116-25.
165. Griffiths S, Sapirstein A, Guzman J, Soriano Z, Ravitz A. Automated, Web-Based Solution for Bidirectional EHR–Infusion Pump Communication. Biomedical Instrumentation & Technology. 2019:30-7.
166. Kumar RB, Goren ND, Stark DE, Wall DP, Longhurst CA. Automated integration of continuous glucose monitor data in the electronic health record using consumer technology. J Am Med Inform Assoc. 2016;23(3):532-7.
167. Capurro D, Echeverry A, Figueroa R, Guiñez S, Taramasco C, Galindo C, et al. Chile's National Center for Health Information Systems: A Public-Private Partnership to Foster Health Care Information Interoperability. Precision Healthcare through Informatics. 2017:693-5.
168. Tubaishat A. Evaluation of Electronic Health Record Implementation in Hospitals. Comput Inform Nurs. 2017;35(7):364-72.
169. Fragidis LL, Chatzoglou PD, Aggelidis VP. Integrated Nationwide Electronic Health Records system: Semi-distributed architecture approach. Technol Health Care. 2016;24(6):827-42.
170. Balis C, Tagopoulos I, Dimola K. Moving Towards a Blockchain-Based Healthcare Information System. Studies in health technology and informatics. 2019;262:168-71.
171. Prusch AE, Suess TM, Paoletti RD, Olin ST, Watts SD. Integrating technology to improve medication administration. Am J Health Syst Pharm. 2011;68(9):835-42.
172. Nolan B. The Interaction of Public and Private Health Insurance: Ireland as a Case Study. The Geneva Papers on Risk and Insurance - Issues and Practice. 2006;31(4):633-49.
173. van Pelt V, Sprenger M. ANTILOPE - Adoption and take up of standards and profiles for eHealth Interoperability. 2015.
174. Chen TL, Chung YF, Lin FY. A study on agent-based secure scheme for electronic medical record system. J Med Syst. 2012;36(3):1345-57.
175. Vuokko R, Makela-Bengs P, Hypponen H, Lindqvist M, Doupi P. Impacts of structuring the electronic health record: Results of a systematic literature review from the perspective of secondary use of patient data. Int J Med Inform. 2017;97:293-303.
176. Andersen P, Lindgaard AM, Prgomet M, Creswick N, Westbrook JI. Mobile and fixed computer use by doctors and nurses on hospital wards: multi-method study on the relationships between clinician role, clinical task, and device choice. Journal of medical Internet research. 2009;11(3):e32.
177. Blackley SV, Huynh J, Wang L, Korach Z, Zhou L. Speech recognition for clinical documentation from 1990 to 2018: a systematic review. J Am Med Inform Assoc. 2019;26(4):324-38.
178. Grant J. EHR: From paper to electronic Plan ahead, avoid common pitfalls for successful integration into practice. Ophthalmology Times. 2010.
179. Add on Data. 5 Key Benefits of Computer on Wheels (COW) in Healthcare & Hospitals 2018 [Available from: https://www.addondata.com/2018/02/5-key-benefits-computer-wheels-cow-healthcare-hospitals/.

180. Toivonen R, Choi D, Nevala N. Ergonomics Product Development of a Mobile Workstation for Health Care. Journal of Usability Studies. 2011;7(1):40-50.
181. Akridge J. EMRs adding wows to COWs. Healthcare Purchasing News 2009.
182. Maxwell J, Cho T, Rudkin S, Wong A, Almassi N, Barton E. Mobile COWs (Computer on Wheels): Hamburger or VEAL? West J Emerg Med. 2016;17(5):527-30.
183. Parker C, Baldwin K. Mobile device improves documentation workflow and nurse satisfaction. CARING Newsletter. 2008.
184. Preuveneers D, Naqvi NZ, Ramakrishnan A, Berbers Y, Joosen W. Adaptive Dissemination for Mobile Electronic Health Record Applications with Proactive Situational Awareness. 2016 49th Hawaii International Conference on System Sciences (HICSS)2016. p. 3229-38.
185. Jinadatha C, Villamaria FC, Coppin JD, Dale CR, Williams MD, Whitworth R, et al. Interaction of healthcare worker hands and portable medical equipment: a sequence analysis to show potential transmission opportunities. BMC Infect Dis. 2017;17(1):800.
186. Beam E, Gibbs S, Hewlett A, Iwen P, Nuss S, Smith P. Evaluating Isolation Behaviors by Nurses Using Mobile Computer Workstations at the Bedside. Computers, Informatics, Nursing. 2016;24(9):387-92.
187. Krogh PR, Rough S, Thomley S. Comparison of two personal-computer-based mobile devices to support pharmacists' clinical documentation. Am J Health Syst Pharm. 2008;65(2):154-7.
188. Rao S, Adam T, Gensinger R, Westra B. Study of the factors that promoted the implementation of Electronic Medical Record on iPads at Two Emergency Departments. AMIA Annu Symp Proc. 2012:744-52.
189. Kume N, Naoki Ohboshi Y, Tadamasa Takemura K, Araki K, Yoshihara H. The Mobile Environment of EHR Browsing Verified on Tablet Terminal. The 6th International Conference on Soft Computing and Intelligent Systems, and The 13th International Symposium on Advanced Intelligence Systems; USA2012.
190. Lenhnbom C, Adams K, Day R, Westbrook J, Baysari M. iPad use during ward rounds: An observational study Investing in E-Health: People, Knowledge and Technology for a Healthy Future. 2014:67-73.
191. Wager K, Schaffner M, Foulois B, Swanson Kazley A, Parker C, Walo H. Comparison of the Quality and Timeliness of Vital Signs Data Using Three Different Data-Entry Devices. Computers, Informatics, Nursing. 2010;28(4):205-12.
192. Rutala W, Weber D, Healthcare Infection Control Practices Advisory Committee (HICPAC). Guideline for Disinfection and Sterilization in Healthcare Facilities, 2008: Update: May 2019. 2019.
193. Po JL, Burke R, Sulis C, Carling PC. Dangerous cows: an analysis of disinfection cleaning of computer keyboards on wheels. Am J Infect Control. 2009;37(9):778-80.
194. HL7. HL7 Fast Healthcare Interoperability Resourcing (v4.0.0). 2018.
195. Health Information and Quality Authority (HIQA). Recommendations regarding the adoption of SNOMED Clinical Terms as the Clinical Terminology for Ireland. Ireland; 2014.
196. World Health Organisation. International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10)-WHO Version. 2016.
197. SNOMED International. SNOMED CT Starter Guide. 2017.
198. California Healthcare Group. Clinical Documentation: EHR Deployment Techniques. 2010.
199. Saranto K, Kinnunen UM, Kivekas E, Lappalainen AM, Liljamo P, Rajalahti E, et al. Impacts of structuring nursing records: a systematic review. Scand J Caring Sci. 2014;28(4):629-47.
200. Rosenbloom ST, Miller RA, Johnson KB, Elkin PL, Brown SH. Interface terminologies: facilitating direct entry of clinical data into electronic health record systems. J Am Med Inform Assoc. 2006;13(3):277-88.
201. SNOMED International. SNOMED International: Leading healthcare terminology worldwide 2019 [Available from: http://www.snomed.org/.

202. Bronnert J, Masarie C, Naeymi-Rad F, Rose E, Aldin G. Problem-Centered Care Delivery: How Interface Terminology Makes Standardized Health Information Possible. Journal of AHIMA. 2012;83(7):30-5.
203. Kalra D. Electronic Health Record Standards. IMIA Yearbook of Medical Informatics. 2006:136-44.
204. Houser S, Morgan D, Clements K, Hart-Hester S. Assessing the Planning and Implementation Strategies for the ICD-10-CM/PCS Coding Transition in Alabama Hospital. Perspectives in Health Information Management. 2013.
205. The Office of the National Coordinator for Health Information Technology. Standard Nursing Terminologies: A Landscape Analysis. 2017.
206. Sundling KE, Kurtycz DFI. Standardized terminology systems in cytopathology. Diagn Cytopathol. 2019;47(1):53-63.
207. Zhang R, Liu J, Han Z, Liu L. RBTBAC: Secure Access and Management of EHR Data. International Conference on Information Society 2011.
208. McCall C. Opt-out digital health records cause debate in Australia. The Lancet. 2018;392:372.
209. National Health Service (NHS). iLINKS Information Sharing Framework. 2016.
210. it Governance. GDPR: When do you need to seek consent? 2017 [Available from: https://www.itgovernance.eu/blog/en/gdpr-when-do-you-need-to-seek-consent.
211. Hoerbst A, Ammenwerth E. Electronic health records. A systematic review on quality requirements. Methods Inf Med. 2010;49(4):320-36.
212. Ministry of Communications and Information. Public report on the committee of inquiry into the cyber attack on singapore health services private limtied's patient database on or around 27 June 2018 Singapore; 2019.
213. Hussain MI, Reynolds TL, Zheng K. Medication safety alert fatigue may be reduced via interaction design and clinical role tailoring: a systematic review. Journal of the American Medical Informatics Association. 2019.
214. Wright A, Aaron S, Sittig DF. Testing electronic health records in the "production" environment: an essential step in the journey to a safe and effective health care system. J Am Med Inform Assoc. 2017;24(1):188-92.
215. The Pew Charitable Trusts. Ways to Improve Electronic Health Record Safety 2018.
216. Corrao NJ, Robinson AG, Swiernik MA, Naeim A. Importance of testing for usability when selecting and implementing an electronic health or medical record system. J Oncol Pract. 2010;6(3):120-4.
217. The Office of the National Coordinator for Health Information Technology. Electronic Health Record (EHR) System Testing Plan. 2016.
218. Rizvi RF, Marquard JL, Hultman GM, Adam TJ, Harder KA, Melton GB. Usability Evaluation of Electronic Health Record System around Clinical Notes Usage-An Ethnographic Study. Appl Clin Inform. 2017;8(4):1095-105.
219. Pereira R, Duarte J, Salazar M, Santos M, Neves J, Abelha A, et al. Usability Evaluation of Electronic Health Record. IEEE EMBS International Conference on Biomedical Engineering and Sciences. 2012:359-64.

Appendix A.

Key Learnings from the Implementation of the Maternal and Newborn-Clinical Information System (MN-CMS) in Ireland

1. Background

The Maternal and Newborn-Clinical Information System (MN-CMS) provides a single Electronic Health Record (EHR) for all women and babies across maternity services in Ireland. This was the first national shared maternity EHR with this level of integration ever implemented. The MN-CMS is built on the Cerner Millennium platform and was initially implemented across four maternity hospitals with a further roll-out to the remaining 15 maternity sites in Ireland planned. The first MN-CMS Go Live was on Saturday December 3rd 2016 at Cork University Maternity Hospital (CUMH), followed by University Hospital Kerry (UHK) in March 2017, the Rotunda Maternity Hospital in November 2017 and National Maternity Hospital (Holles Street) in January 2018. Currently 40% of all births nationally are recorded on the MN-CMS and there are approximately 3,200 users [27]. The aim of this report was to summarise the key learnings related to implementation of the national MN-CMS across the four hospital sites.

2. Methods

2.1 Data collection

At each implementation site, workshops were held with end-users, the vendor, national project team, national back office and management consultants within three months of Go Live. Additional feedback was received using structured lessons logs, small local debrief meetings and emails. These learnings were collated by each individual site into four reports.

2.2 Data analysis

Each of these four reports were reviewed by an independent researcher who was not involved in the implementation of the EHR or the collection of the anonymised data. Following initial review of the data, it was identified that these data corresponded with the findings from the international literature. An inductive and deductive content analysis was applied to these data using the same framework derived from the review of the international literature [38]. The four reports were coded using this framework and collated under the Organisational, Human and Technological Factors. Direct quotations from the report were also extracted to support the findings.

3. Key Learnings: Organisational Factors

3.1 Governance, Leadership and Culture

The key learnings from the implementation of the national MN-CMS highlight the importance of creating an open and supportive culture, having good clinical leadership and communication between all parties (HSE, Vendor, Local Site), and clear delineation of roles and responsibilities amongst the project team. These learnings are discussed in further detail below.

3.1.1 Governance Structure

- National and local roles and responsibilities need to be finalised and circulated to avoid confusion.
- HSE should have a national and local governance structure which facilitates clinical input in the technology.

- HSE should have a strategy for cross programme collaboration with consideration of local support mechanisms, data migration, testing, training and change management, and take critical dependencies into account e.g. MedLIS project.
- Agree, document and circulate national policies, strategies and communications plans as soon as possible.
- National team should engage local site.
- Need to embed the EHR within the governance structure of the organisation.
- Hold integrated meetings for all stakeholders during the go-live period rather than separate site and project meetings.
- Need post Go Live planning including clarifying the roles and resourcing of the local back office, lab and pharmacy support, super-users, trainers and ICT teams.

Vendor-organisation Relationship

- Need confirmation by HSE and Vendor of who is responsible for defining the domain strategy
- Allocate local hospital and vendor leads with both parties agreeing on the strategy.
- Formalised method of timely communication between vendor, national project team, workstream members and local sites regarding project planning, status of items, identifying possible risks, existing issues etc. (e.g., weekly calls worked well).
- Vendor should provide a clear, transparent disaster recovery strategy to healthcare organisations.
- Alterations to contracted plans require Contract Change Notifications (CCNs) irrespective of whether additional changes are attracted or not to enable discussion and implications of charges and appropriate documentation.

3.1.2 EHR project management

- Need project management strategy at each site.
- Hold integrated meetings for all stakeholders during the go-live period rather than separate site and project meetings.
- Augment project team with leaders from other live sites who have EHR experience and can ensure project tasks are completed on schedule.
- Need to consider leaders beyond project management such as those to address clinical workflows and other projects which need to integrate with the EHR (e.g., MedLIS).
- Multiple roles held by project team members impacted on their ability to complete tasks on time and some tasks should be allocated to other staff (e.g., testing).
- Develop a clear decision-making process which identifies responsibilities which empowers project team members and enables effective time management.
- Assign 'owners' to different activities within the project plan.
- Local Implementation Team meetings:
    - Increase in frequency as Go Live approaches.
    - Project issues and risks need to be flagged and reviewed during each meeting.
    - Need to continue (potentially in a revised format) post Go Live to support the transition.

Consultant led multidisciplinary medication management group is required to lead and manage on MN-CMS medication related issues

EHR Implementation Approach

- Reduce elective surgery lists, number outpatient clinics or patients per clinic attendances for the first week of Go live (enables staff to build confidence and speed with the system).
- Where paper and EHR utilised in parallel:
    - Need early access to charts.
    - Staff aware of processes for transferring patients between wards with/without EHR (e.g., ensure outstanding orders completed before transfer).
- Time intensive and requires dedicated resources (data migration resources calculator has been developed).

- Need a data migration strategy.
- Manually migrate large volumes of patient clinical data/charts in advance of Go Live to avoid on-the-spot migration (lengthy process for frontline staff and frustrating for patients).
- Migrate inpatient and ED visits from iPMS at time of Go Live.
- Data migration team:
    - Should include competent system users with understanding of the data configured on iPMS.
    - Could include the trainers (CUMH).
    - Should be on duty at go live to migrate any data missed.

3.1.3 Local Leaders

Having engaged, senior clinical leaders onsite leading the project ensured many issues were rapidly resolved

- Need to engage senior management.
- Senior leaders need to be visible by visiting wards and discussing challenges facing clinical staff.
- Schedule senior staff (preferably a clinician and the ICT Lead) to daily round wards during Go Live and then less frequently during the transition phase after Go Live (minimum weekly).
- Champions need to be identified from within all departments (e.g., ED) in order to embed the system.
- Impact of champions should not be underestimated.
- Identify project champions early and ensure their role and responsibilities are known by them, the project team and the wider staff.
- Provide champions with support if required to fulfil role.
- Need to make staff aware of training requirements.

3.1.4 Organisational Culture

The Conversion Readiness Assessment document should be started earlier; incredible detail required and this time-consuming task was left until very close to Go Live

- Communication and sharing of knowledge and technology lessons learnt between sites and between local and national medical teams.
- Communication style and format, as well as any materials, should be adapted and tailored to reflect the local culture, customs and ongoing practice (use previous examples as templates).
- Welcoming atmosphere and operational readiness facilitated implementation.

Huddles during Go Live gave us great awareness of what was happening on the wards; the simple structure ensured good communication and

- Daily centralised huddles between super users, clinical staff, floor walkers and external support staff should be used to review progress and allocate resources.
- Managers and other key staff (e.g. Labs/Pharmacy) not attending huddles need to be informed of progress via rounding/visiting all wards to provide updates.
- Communication between leaders and end-users is very important and should include:
    - Relevant policies in advance of Go Live.
    - Project progress and status.
    - Provide advance notice of key activities (training, information sessions, status of project, username setup and testing, handovers).
    - Process of reporting of issues: key people and escalation pathway to the national project office.
    - Issues resolved to be passed onto end-users.
    - Use of Whatsapp groups recommended.

3.2 End-user involvement

According to the learnings from the MN-CMS implementation, a clinically-led design phase ensured the system met the needs of end-users, whilst lack of involvement leads to a lot of rework. The following was recommended in relation to getting end-user involvement and where it is needed:

- Need stakeholder representation and involvement as early as possible (including IT, clinical and admin staff).
- National and local governance structures should allow clinical input to help identify and resolve workflow issues.
- Login process requires agreement amongst all users ahead of Go Live.
- Need to involve doctors despite their lack of availability (e.g., use local champions or national clinical leaders to promote involvement).

3.3 Training

Learnings in relation to training were discussed in terms of who provided the training, the content included and the timing and planning of training:

Training methods

- Evaluate training with feedback tools.
- Plan to support NCHD knowledge and skills recommended.
- Development of e-learning specific to the Irish healthcare setting.
- Provide training onsite, ensure room availability and consider availability of back-up software domain for training during down-times.

Training providers

- Confirm levels of responsibility of Vendor and Hospital prior to commencing.
- Training lead responsible for planning, executing and reporting on training.
- Trainers, super-users and testers should not be the same people.
- Trainers should be engaged, motivated, able to manage anxious or negative trainees and troubleshoot basic IT issues.
- Need opportunities to practice and prepare training (reserve 1-2 weeks to prepare super-user training).
- Build in extra capacity when determining numbers of trainers required.
- A pharmacist trainer (or two at larger sites) should deliver training on medication-related elements.
- Identify local team capabilities and streamline training based on training needs (duration of training is a significant burden on the hospital).

Training was delivered by trainers, who were midwives or nurses and input from other disciplines was not incorporated into the schedule e.g. pharmacy. This left many users, especially doctors and anaesthetists, feeling that their medication training was inadequate

Training content

The medications team should be involved in the configuration of the TRAIN domain, test patients and scenarios

- Ensure training reflects live system (i.e., update training if software domain changes, all functions need to be ready and workflows need to be defined and agreed).
- Include formatting data collection worksheets (DCW), how to fill out DCW, relevance of each piece of information and how DCW will be used.
- Include printing of requisitions and order slips, order communications, Powerchart and how to resolve common errors in training.
- Targeted training for specific disciplines (including admin and admissions staff).

- Super-users need tailored training for specific role before other end-users and need additional training to ensure they can support and resolve issues arising.
- Deliver at ward level with actual device to reassure end-users and identify issues.

Ensure training covers how to troubleshoot – many issues were expected, but still hard to manage

Timing of training

- Training should be held within 6-8 weeks of Go Live.
- Senior management and champions should be aware of training requirements.
- Need to include all staff and run through workflow from start to finish (e.g., administrative, admissions, phlebotomists).

Training programme took place many weeks before Go Live due to a decision to push back the Go Live date while training was already in progress and although supplementary training was arranged on an as needed basis, staff felt unprepared despite these refresher sessions

- Ensure staff availability (doctors had limited availability to attend):
    - Use of overtime, annual leave reductions and backfilling.
    - Flexibility in clinical work to facilitate completion of full training sessions (e.g., flexible delivery times).
    - Work with clinical leads to schedule appropriately timed sessions.
    - Need to engage medical staff.
    - Schedule training for specific areas well in advance (little notice resulted in all disciplines attending during the same week).
    - Ensure staff backfill.

Ongoing and Refresher Training

- Refresher training on basic concepts (e.g., correct logging off, keep devices charged, printing and scanning) should be available to all leading up to Go Live.
- Opportunities to practice system with drop-in sessions, video lessons and protected time.
- Training for new staff, staff turnover into new wards and agency/locum staff required.
- Re-assessment of training needs on an ongoing basis to embed it within the working culture.

3.4 End-user support

Allocation of sufficient and consistent support during and after Go Live is of utmost importance. Those involved in the implementation of the MN-CMS discussed support provided by the Command Centre, Super-users, Floor-walkers and Guides. These support staff were provided by the organisation themselves, multi-disciplinary teams from other sites and the vendor. However, one of the key learnings from the MN-CMS implementation was to ensure post Go Live support is planned and clear amongst local IT, HSE, CIO and vendor. The level of support required shifted as the system stabilises and users become more familiar, but the site needs to be clear on the available support at the time of handover from vendor to hospital (hospital needs to be able to troubleshoot system independently).

Command centre support

- Specialist support staff for specific functions of EHR present in Ireland (e.g., Fetalink).
- Dedicated password reset available 24/7 (especially for first 2-3 hours of shift).
- Available day and night (gaps in support during night shifts led to significant user frustration)
- Dedicated clinical resource with local knowledges required to triage issues, resolve quick queries and ensure appropriate prioritisation of those logged.
- Plan Go Live roster well in advance and review on an ongoing basis to ensure appropriate staffing.
- Consider reducing shift duration and factor in break times.

Our resourcing plan was only up to Go Live and the transition was a real challenge; Go Live is just the beginning so make sure you plan (and allocate resources) for the transition

- Large room with dedicated phone lines, Wi-Fi, PCs and printers required.
- Need basic Millennium overview (screenshots, cheat sheets, system demonstration).
- Issue routing and resolution should be planned and agree upon single issue logging platform.
- Share help desk phone numbers with frontline staff and clarify issue logging process.
- Put methods in place to update users on status of issues logged.
- Staff should stop by each ward to ensure all end-users able to access system (particularly during night shift).
- Schedule a dress rehearsal to practice routing for call centre staff.

Super-users:

- Need to build effective local support capability through training, system practice and refresher courses.
- Need early and constant engagement using site visits of live systems, communication with super-users at these sites and using super-user huddles (don't revert back to solely clinical role after training).
- Need to cover day and night shifts (24/7) during Go Live.
- Super-users should have electronic checklists in initial days (avoid paper checklists).
- Local clinical managers should be appointed as super-users (where self-nomination, many didn't take the role on and then felt unprepared for change).
- Super-users, trainers and testers should not be the same people.
- If feasible and required, appoint trainers to take on super-user role during Go Live.
- Need cohort of supernumerary super-users to provide support during Go-Live.
- Ensure super-users released from some clinical duties during Go Live.
- Avoid burnout of support staff with breaks, access to meals and limit shifts to allocated time only or reduce shift length.

Frontline pharmacist availability enabled pharmacy support from 7.30am – 11pm/midnight on most days for the first two weeks

Floor walkers/Adoption Coaches:

- Mixed opinions regarding numbers of floorwalkers between early and later Go Live sites (some said there were too many and others recommended more).
- Very positive impact of floor walkers provided by vendor on end-user adoption.

Guides:

- Provide 'tip sheets' on wards regarding common problems and how to log on and off.
- Share support guides for all key processes across different Go Live sites.
- Simplify tools and make easily accessible.
- Quick reference guides created by HSE, Vendor and IT Consultancy firms should be simplified, streamlined, easily accessible and accurate.
- Resources needed to prepare/update local quick reference guides.

3.5 Resourcing

Financial, time and workforce resources need to be planned for during an EHR implementation and similar to international findings, the MN-CMS project reported "*underestimating the volume of work and resources required at the outset*". Learnings from the MN-CMS data recommend the identification of gaps in resources and development of plans to augment these resources prior to implementation from national and external sources. The following were the key learnings in relation to financial resourcing, time and staffing.

3.5.1 Financial

- Need a contingency budget for more equipment (once users started using devices they requested more).
- Use business case approach to get more resources.
- Additional funding required to replace older monitors (older monitors did not have facility to output readings).

Our resourcing plan was only up to Go Live and the transition was a real challenge; Go Live is just the beginning so make sure you plan (and allocate resources) for the transition

3.5.2 Time

- Need realistic timelines which are reviewed weekly with local and national team to ensure they are aligned.
- Ensure time for training staff (which may require reduced workloads, overtime or reduced annual leave).
- Ensure time for testing, device set-up and data migration (Underestimation of time resulted in delays e.g., device set-up, order communications).
- Large number of meetings requires planning as they reduce available worktime.
- Set and meet intermediary project "deadlines" for long duration tasks.
- BMDI Connectivity Tests should start early to facilitate more time Unit & Integrated testing.
- Plan the roll out of usernames and passwords to ensure that all staff have access to the system in time for Go Live (consider holidays, night shifts, weekend work).
- Need to plan for device delivery early (delivery timeframes were too late and put IT staff under pressure) – could use sample carts to begin if needed.
- Time should be allowed to ensure reconfiguration of pump servers can be accommodated if necessary.
- Vendor and HSE need to agree timeline for device testing and issue resolution in advance of Go Live.
- Operational dress rehearsal needs to be priorities to minimise challenges encountered in Go Live.
- Time limit should be established for closing off issues so that they do not carry over to the next site.

Build continued right up to the Go Live, including critical build such as NICU complex infusions; very little breathing space between the completion of the build and Go Live

3.5.3 Workforce

- Staff turnover was a barrier and particularly difficult for smaller sites who rely on locum staff.
- Assess local site staffing availability against required project roles – identified gaps should be reported to national project team as early as possible.
- Provide local telephone numbers to non-Irish staff to improve communication and facilitate engagement.
- Develop local resource plan that includes project team, training and testing requirements.
- Need people available and capable to undertake roles at a local level.
- Underestimation of staffing needs led to staff taking on multiple roles, need for staffing from external contractors and delays or incomplete change activities (particularly for change management support).
- Project scale should not be underestimated and typical international staffing ratios should be considered to ensure appropriate staffing levels.
- Back office role assessment must be completed in the scoping phase of future projects to ensure sufficient time for recruitment and training.
- Staff rostering to ensure all staff attend training and super-users available 24/7 – rosters should be visible and available.
- Ensure staffing requirements are clear to allow better planning of these activities.
- Need for more staff in the first 5 days.

Plan the pharmacists' roster for Go Live early to ensure best use of limited available resources

- When rostering staff over go live ensure that at least one experienced staff member is on each shift (particularly an issue on weekends/overnight).
- Data migration is time intensive and dedicated resources are required.
- Large numbers of calls, broad invite lists, and the multiple roles held by staff resulted in attending back-to-back meetings with reduced available work time:
    - Prepare agendas in advance (can be standing agenda for regular meetings).
    - Clarify the objectives, frequency, duration and required attendees for meetings (based on workstream or discipline).
    - Review invite list.
    - Devise formalised process for following up on meeting items and adjust meeting requirements as milestones completed.

3.6 Workflows

The following learnings were identified in relation to identifying end-user workflows:

- Establish clear guidelines for the project team on what can be accommodated within the system for local workflows.
- Need dedicated time to review workflows with users (not during training time).

Medications workstream can't be managed in isolation – it should be integrated with other work streams

- Staff need to understand local workflows (not all vendor staff did).
- Knowledge of entire data flow of patient journey and knock-on impacts of any changes.
- All workflows (including ordering processes) need to be developed, tested, thoroughly understood by all end-users and trained prior to Go Live.
- Local and national workflows need to be finalised prior to training of super-users and end-users.
- Identify all changes to workflow and potential challenges or issues (significant impact to pharmacy workflows including discontinuing drugs).
- Any changes to workflow need to be agreed and documented.
- Changes to workflows should be adopted prior to Go Live to minimise the impact of several changes at once.
- Involvement of trainers in local workflow meetings, enables them to answer questions arising during training.

The Start, Stop, Continue process is a great way to identify what's changing for end users

- Where paper and electronic records are used concurrently, work processes need to be understood by all staff to mitigate any risks (e.g., outstanding orders when moving patients between inpatients and outpatients).

4 Key Learnings: Human Factors

4.1 Skills and Characteristics

Lack of basic IT skills made the impact of change larger for some staff and local knowledge and skills (ICT, Biomed) were key to a successful rollout. Therefore, the following learnings from the MN-CMS were highlighted:

- Provide basic IT skills to staff requiring.
- Performance-based competency assessments to identify staff requiring further training.
- Experienced leaders and support staff from live sites should be utilised.
- Increase system knowledge and use it to overcome negative attitudes.

4.2 Perceived Benefits and Incentives

Positive staff attitudes towards the EHR reportedly facilitated implementation of the MN-CMS and to promote positive attitudes the following was recommended:

- Doctors need to understand benefits of attending fairs to engage them to attend.
- Engage staff using social media.

- Pre-project engagement sessions with stakeholders from engineering, IT and clinical backgrounds.
- Develop structured optimisation engagement sessions.
- Celebrate achievements and provide catering facilities.

4.3 Perceived Changes to the Healthcare Ecosystem

Although changes to the work practices are inevitable with an EHR implementation, the perceptions of end-users needs to be managed. In some cases, changes to the roles of frontline staff can be a positive for the health service.

Pharmacy were really valued during Go Live, and are now seen as integral on maternity wards…clinical role has expanded from supporting good prescribing practices and best practice in meds administration to advising staff on use of the drug chart and managing system issues

We need to better manage people's perceptions of what an e-prescribing system is capable of – it does not replace clinical knowledge

5 Key Learnings: Technological Factors

5.1 Usability

To ensure a usable EHR system, the following learnings were identified:

- Login process should:
  - Require single login.
  - Be confirmed earlier than one week prior to Go Live.
  - Should match email branding to maintain standard user login nationally.
  - Minimise desktop login icons to avoid confusion (CUMH/UHK had multiple icons).
- Screen size important (22" recommended by vendor).
- EHR should enable customisation of view for more efficient handovers that don't require paper.
- Use of favourites simplifies documentation and ordering and thus, need to ensure doctors attend information fairs on use of favourites.
- Changes to optimise system need to be timely.

5.2 Interoperability

As legacy systems were in use prior to implementation of the MN-CMS, these systems need to 'talk' effectively with the EHR and this is referred to as interoperability. The following are the key learnings to facilitate interoperability:

- During core set-up of EHR, need to take other systems into account (e.g., PAS).
- Need active management.
- Time, planning and consideration needs to be given to the task of interface switching.
- Ensure third party vendors interface with EHR system using basic trouble shooting prior to integration testing.
- Frequently (weekly) engage and work with third party vendors regarding interface issues to resolve issues effectively.
- Need write access of other databases (e.g., iPMS).
- HSE integration engine would make testing and transition across sites much easier.

5.3 Regulation, Standards and Policies

To ensure data quality across every site, the following was recommended in relation to regulation, standards and policies:

- Data configured in each system must match.
- Standard interface formats should be followed.

- Determine effective approach to embed national identifier into master systems to allow safe merging.
- Agree approach to implement a national rather than local pathology catalogue.

5.4 Infrastructure

Infrastructure refers to both the hardware and software required to run a successful EHR, however the key learnings from the MN-CMS mainly focused on the hardware. It should be noted that sharing of technology-related issues occurring in initial MN-CMS Go Live sites (e.g., connectivity, printer issues) reportedly resulted in these issues being avoided in other sites. The following were the key learnings related infrastructure:

- Need adequate access to power sockets.
- Ensure frequent recharging of carts/setup a recharge schedule (particularly for the label printers which run out of battery quicker than laptops).

In the early days, the system was freezing and dropping its Wi-Fi connection causing frustration to staff

- Map hospital layout for space.
- Encourage vendor to visit site to identify any areas of concern (e.g., wall-mounted computer).
- Need to consider size of large carts.
- Need space to set-up, store and test devices which has sufficient power sockets and connectivity.

Lack of devices for pharmacists, particularly in NICU, meant staff could not take on their usual 'medicines expert' role on the ward round

- Confirm device requirements (including configuration needs), selection and location at the earliest planning stages.
- Ensure all devices compatible with the EHR system (vendor should supply list).
- Include private rooms when planning equipment purchasing & testing.
- Sites where procurement is further away should consider purchasing equipment that will be compatible with the planned vendor software.
- Dedicated resources for cart setup and build are required and this should be completed as early as possible to ensure devices available in wards 2 weeks before Go Live (device set-up is time-consuming).
- Devices and equipment should be available for testing and training dates prior to Go-Live (more rigorous testing, early identification of problems and more time for front line users to train and practice).
- Device configuration (e.g. cart design) needs to support end users and local IT teams.
- Provide practice sessions on setting up and reloading devices.
- Additional funding required to replace older monitors (older monitors did not have facility to output readings).
- Assess impact of different devices on workflow.
- Final check before Go Live to ensure sufficient technology available to maintain services.
- Share list and types of devices utilised with other sites.
- Also required central whiteboards, mouse pads, carts, scanners.
- Hardware and software to facilitate conference calls (e.g., Lync, Skype).
- Printers:
  - Need simple printing function.
  - National team has a role to ensure printing is a major priority during preparation for each new site.
  - Need dedicated printing owner allocated from vendor and HSE.
- Wrist bands and scanners:
  - Define wristband and barcode requirements and confirm responsibility for associated tasks during the scoping phase.
  - Multiple bands required for each patient (e.g., Millennium, iPM, blood tracking etc).

- Need at least one label printer and one requisition printer in the lab areas during testing phases.
- Setup barcode scanners to only activate when trigger is pulled (movement of cart triggered laser).

5.5 Adaptability

Whilst adaptability refers to the capacity of the software to be adapted, the learnings from the MN-CMS refer mainly to the process of adapting and changing the software. Change suggestions were numerous at Go Live but need to follow correct change process at all times which should include:

- Assessment of change request from all points of view (e.g., work effort estimation, end-user/clinical impact, integration impact, workarounds available).
- Changes should be documented and agreed with the HSE.
- Updating all documents prior to implementing any change (e.g., training guides and data collection worksheets).

5.6 Testing

Compared to the international literature, testing was extensively discussed in the MN-CMS learnings and the key areas are outlined below:

- Vendor should provide a fully functioning interface which they have trouble shooted
- Organisation should then perform testing:
  - On most recent and up-to-date database.
  - Early in project to allow sufficient time to re-write and refine where required.
  - On detailed and specific test scripts (e.g. Dose Range Checking, Pharmacy Care Organiser) and these should be revised as required.
  - Set testing exit criteria for proceeding to next stage of testing.
  - On all aspects including wristbands, Fetalink, Anesthesia, Lab pools.
- Testing needs to be finished prior to training and requires vendor and client to agree on a final date.
- When mapping and testing Wi-Fi connectivity:
  - Use actual devices and EHR application (some laptop carts experienced connectivity issues that were only identified during Go Live).
  - Test in all areas of hospital.
  - Practice actual workflows (ensure mobile devices stay connected as they are moved around wards).
  - Load the network with the expected volumes of traffic.
  - Ensure support staff have access to good Wi-Fi especially at time of Go Live (significant extra staffing may be beyond 'guest' network limit).
  - Clarify vendor's responsibility in assessing connectivity.
- A central testing team should be established that can cover the basic functionality testing, while local teams focus on site-specific workflows.
- Local testing teams:
  - Need to be available for testing (including lab staff).
  - Trainers should not be testers as integration testing is usually scheduled around training timelines.
  - A staff member with knowledge of both iPMS and Millennium is required to ensure testing is appropriate and detailed.
  - Staff from other live sites were knowledgeable and proficient in testing approach.
- Setup a practice medical ward round to ensure doctors are clear on new workflows and have tested it prior to Go Live.
- Switch on laboratory orders in advance of Go Live weekend to allow time to investigate any issues.

6 Conclusion

The key learnings from the national MN-CMS implementation support the importance of the key factors identified by the international literature for the successful implementation of the EHR. Whilst limitations to these data exist as they were collected at a single time point and the original transcripts were not available to the researcher, many similar findings were noted compared to the peer-reviewed international literature. Additionally, these data refer to the implementation of an EHR specifically for maternity and newborn, and this context needs to be considered when interpreting the findings. For example, data migration from a paper chart to digital format may be simpler for this population compared to an older adult with a chronic illness. However, overall these findings provide a great insight into a national implementation of health information technology (HIT) within the Irish health system. The benefits of sharing learnings between Live and prospective sites is clear and should continue as Ireland continues to embark on the implementation of the EHR.

Appendix B.

Search Terms

Electronic Health Record			Implementation		Literature review
Electronic Health Record*	*Electronic health record*	AND	Implement*	AND	*Systematic Review*
Electronic Healthcare Record*	*Electronic health records*		Introduc*		*Scoping Review*
Electronic patient record*	*Electronic medical record*		Adopt*		*Meta Analysis*
Computeri?ed health record*	*Computerized medical records*		Develop*		Literature review
Electronic medical record*	*Automated medical records*		Establish*		Systematic review
Online health record*	*Medical Order Entry Systems*		Process*		Scoping review
Digital health record*	*Electronic Order Entry*		Execut*		Meta-analysis
Computeri?ed medical record*	*Computerized provider order entry*		Employ*		Meta-synthesis
Electronic Medical Record	*Health Information Systems*		Instigat*		Systematic interpretive review
Automated medical records	*Medical records system, Computerized*		Launch*		Systematic methodological review
Electronic Record System*	*Electronic health record system*		Re-launch*		Systematic meta-review
Clinical Information system*	*Medical information system*		Commenc*		Systematic literature review
Electronic Health Record System*	*Patient Portals*		Initiat*		Qualitative synthesis
Medical Information System	*Health Information Interoperability*		Uptake*		
Computeri?ed medical systems	*Data interoperability*		Configuration*		
Clinical data repositor*	*Interoperability*		Customi?ation*		
Health Records System*	*Health Information Exchange*		Re-optimi*		
Medical Records System*	*Medical Record Linkage*		Optimi*		
Health information system*	EHR		Rollout*		
Hospital information system*	PHR		Evaluat*		
Electronic prescribing	EHCR		Assess*		
eprescri* OR e-prescri*	EPR		Design		
Electronic pharmaceutical record	EMR		Facilitate*		
Electronic Order Entry	CIS		Barrier*		
Computerized ordering	EHRS		Challeng*		
Medical Order Entry System*	DIS		Benefit*		
Drug Information System	CPOM		Success		
Order comm*	CPOE		Failure		
Computeri?ed Physician Order Management	EPR		*Systems Development*		
Computeri?ed Provider Order Entry	EHRS		*Systems Implementation*		
Computeri?ed Provider Order Management					
Computeri?ed Physician Order Entry					
Personal health record*					
Patient health record*					
Patient portal*					
Shared care record*					
Summary care record*					
Patient data repositor*					

Note: Italicised terms relate to subject headings which were exploded in the relevant databases; *, truncation i.e., locating all terms that begin with the given string of text; ?, wildcard, i.e., replaces one character within the word; Boolean operator "AND" was used to combine searches for terms related to electronic health record AND implementation AND literature review; Boolean operator 'NOT' was used to exclude "hypoxic-ischaemic encephalopathy", "endoscopic mucosal resection", "electromagnetic radiation", "eastern Mediterranean region".

www.hseprint.ie