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Research article

Understanding optimisation processes of electronic health records (EHRs) in select leading hospitals: a qualitative study

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ABSTRACT

Background Little is known about optimisation of electronic health records (EHRs) systems in the hospital setting while adoption of EHR systems continues in the United States.

Objective To understand optimisation processes of EHR systems undertaken in leading healthcare organisations in the United States.

Methods Informed by a grounded theory approach, a qualitative study was undertaken that involved 11 in-depth interviews and a focus group with the EHR experts from the high performing healthcare organisations across the United States.

Results The study describes EHR optimisation processes characterised by prioritising exponentially increasing requests with predominant focus on improving efficiency of EHR, building optimisation teams or advisory groups and standardisation. The study discusses 16 types of optimisation that interdependently produced 16 results along with identifying 11 barriers and 20 facilitators to optimisation.

Conclusions The study describes overall experiences of optimising EHRs in select high performing healthcare organisations in the US. The findings highlight the importance of optimising the EHR after, and even before, go-live and dedicating resources exclusively for optimisation.

Keywords: electronic health records and systems, clinical information systems, inpatient (inpatient CPOE), system improvement, facilitators, barriers

BACKGROUND

There is little documentation about optimisation of electronic health records (EHR) systems, namely, the process that takes place after implementation to maximise the benefits and utility of the system. Such optimisation following the go-live is critical to successful implementation in ambulatory settings.[1–3] Despite the importance of EHR optimisation, little attention is given to this critical process in hospital settings. Too often, implementation of the EHR is considered complete once the system goes live. Optimisation of the system is usually an afterthought. Many studies about EHR, including those on unintended consequences associated with EHR systems, have predominantly focused on implementation and do not take optimisation into consideration.[4–6] In reality, however, experts in health information technology say: 'It's one thing to go live and a *completely different* thing to see it through'.[7] In addition, early adopters of EHR systems and documented studies emphasise the importance of the optimisation process.[7–12]

This study is one of the first attempts to systematically understand and describe EHR optimisation efforts undertaken in hospital settings. As US hospitals continue to adopt EHR systems, documenting the experience of EHR optimisation efforts taking place at leading healthcare organisations will provide valuable insights on how to leverage EHR systems in the post go-live era.[13–15] This insight may also benefit healthcare organisations that plan to adopt an EHR system by providing valuable information that helps decision-makers to establish a plan for both the implementation and optimisation phases. Additionally, this study may help to prevent the waste of resources caused by failed EHR implementations.

Our objective is to understand the optimisation processes undertaken in high-performing hospitals following EHR implementation. The main research questions were: 1) What strategies do hospitals with implemented EHR systems employ to realise the benefits of the deployed systems or to meaningfully use the systems? 2) What advancements are hospitals making, post go-live, to leverage the EHR system? 3) Are there any pattern(s) of optimisation processes in hospitals and, if so, what are they specifically? 4) What are barriers and facilitators to optimisation? 5) How do organisations define and conceptualise EHR optimisation?

METHODS

Study design

Informed by a grounded theory approach,[16] a qualitative study was conducted that included in-depth interviews and a focus group with subject matter experts from healthcare organisations across the United States.

Sampling and recruitment

In order to include a diverse sample of participants, we pursued a purposive sampling approach. The sampling process is described as shown in Figure 1. We created a list of potential participants from five sources that identified high-performing healthcare organisations, which consisted of the Healthcare Information and Management Systems Society (HIMSS) Davies Award winners (33 healthcare organisations); Baldrige Award recipients (9); the 2014–2015 Best Hospitals Honor Roll by US News & World Report (6); Truven 100 Top Hospitals Winners appearing more than six times (45) and 2013 and 2014 top hospitals by the Leapfrog Group (21). The total number of the organisations was 114, and eight duplicate organisations were excluded, which resulted in a total of 106 candidates. Originally, the sources gave a much larger number of candidates, but exclusion criteria were applied. Any organisation with less than 100 beds was excluded. Also, any organisation located too far (requiring more than 10-hour driving) was removed for practical reasons. However, HIMSS Davies winners were not excluded based on location due to their significance.

From the list, 970 individual participant candidates were identified, using a professional membership directory, literature, official organisation websites and an online professional network. Candidates included clinical information system directors/managers, organisational executives, medical directors, physicians, nurses, clinical staff and information technology (IT) professionals. Age, gender, race and ethnicity were not a factor in selecting participants. An email invitation to participate along with a link to the research website was sent to 946 candidates on 10 August 2015. Nineteen candidates responded. An invitation letter was sent by mail to the remaining 24 candidates out of 970, and one candidate responded. Of the 20 respondents, a total of 15 individuals (sample size = 15) representing 13 healthcare organisations across the United States participated in the study. One participant had dual representation for two separate organisations due to a recent employment change. We conducted 11 interviews and one focus group consists of four individuals. The focus group was offered by one participant site. Considering its relatively small size compared to other participant sites, we accepted it as it could present a richer and more diverse description about optimisation. The participants and organisations were summarised in Table 1. The study was reviewed and approved for exempt status by the Human Subjects Division (HSD) at the University of Washington.

Data collection and analysis

In-depth interviews and the focus group session were audio recorded at participants' office locations (3) or by telephone (9) between 20 August 2015 and 21 October 2015, facilitated by the lead investigator by using the Interview Guide included as Appendix A. The investigator was experienced in facilitating interview and practiced an interview with the guide several times before conducting the interviews and focus group. The Interview Guide was developed during the research design and validated by HSD to elicit answers to the research questions. To control comparability of data, the focus group was performed similarly to an interview directed by the Interview Guide, seeking responses from the members of the group who were best able to answer a particular question. A total of 635-minutes of interview and focus group audio recordings were collected, transcribed and analysed. In addition, the documents that were available to the public such as HIMSS

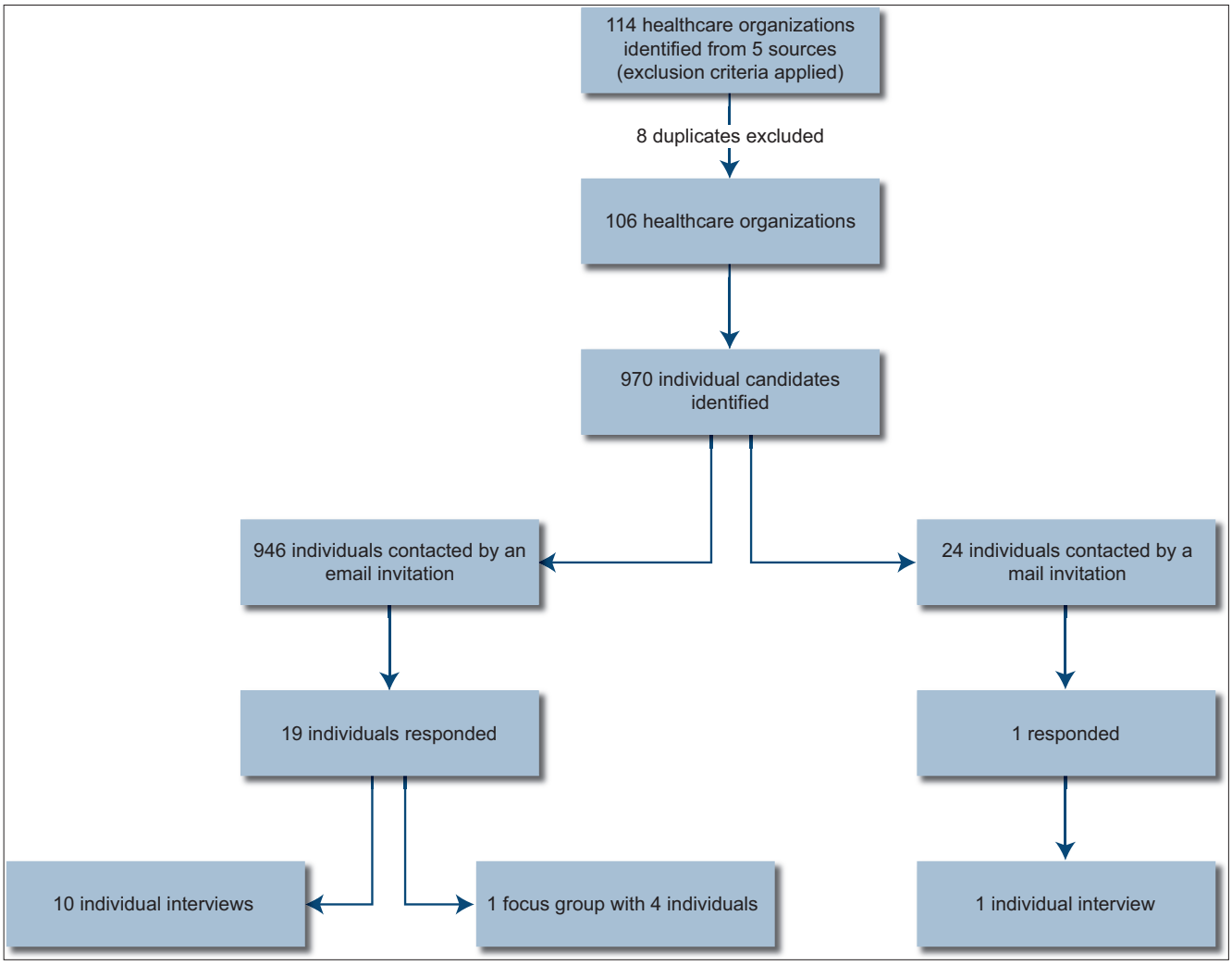

Figure 1 **Sampling process**

Davies Award applications and internal documents provided by the participants were collected and reviewed. The documents that presented reliable and objective information were selected, coded and analysed.

We performed qualitative content analysis informed by a grounded theory approach.[16] First, the study investigator transcribed the interview and focus group recordings. The investigator repeatedly reviewed the audio recordings and transcripts, having in-depth discussions with the research team throughout the data collection process. Second, we drafted a preliminary coding guide, identifying common themes emerging from the interviews and the transcripts and relating them to the research questions. Third, we developed a comprehensive coding guide by identifying sub-themes and relationships between themes. We further refined the complete coding guide during the initial data analysis with five participants' data, merging overlapping codes and simplifying codes. Then, we applied the final coding guide to all data. Lastly, we interpreted analysed data by using Data Analysis Framework with Codes (Appendix B) to answer the research questions and understand the whole picture of optimisation. To strengthen the analysis and increase its accuracy, we had regular discussions throughout the iterative analytic process and utilised qualitative data analysis software ATLAS.ti (v.7.5.10).

RESULTS

The analysis of data revealed the following characteristics of optimisation efforts undertaken at the selected institutions, including optimisation processes, types (goals) and results of optimisation and its barriers and facilitators.

Definition of optimisation

Participants defined optimisation as an ongoing process making the implemented EHR more efficient and usable for end user clinicians that results in improved efficiency in clinicians' practice and satisfaction.

Exponentially increasing requests

After go-live, both requests for fixes and changes increased 'exponentially'. A developer participant reported requests for EHR enhancements '*literally flooded in*' for different end users (P1). Another participant said, '*We have seen … the number of requests go up exponentially. As people feel more familiar with the system, people like to change it, we get more and more requests*' (P4). The exponential surge of requests augmented the participants' workload with a more flexible timeline even after a smooth go-live. Demands for both fixes and optimisation overflowed continuously.

Table 1 Participants and sites

ID	Participant role and backgrounds	Characteristics of organisation	EMR/EHR implementation
P1	Program Management Officer, a primary developer of the EHR system; currently leads communication and marketing team for a program to modernise the system	A public, not-for-profit organisation with 150 medical centres and about 1400 outpatient clinics and facilities	Homegrown system developed in late 1990s; implemented in pilot sites then spread out
P2	Informatics Nurse, helps facilitate the optimisation process, develop and approve policies that relate to the EHR and liaison to different departments	Not-for-profit, integrated health system including 16 acute care hospitals, about 23,000 employees, 3800 licensed beds, 'QUEST Award for High-Value Healthcare' Premier Healthcare Alliance, 'Top Performer on Key Quality Measures'®	Implemented an integrated EHR 2006–2011. First two hospitals implemented in phases, the rest implemented big bang approach. Enterprise HIMSS Davies Award of Excellence
P3	Director of Inpatient Clinical Applications	Not-for-profit, integrated health system including five hospitals with more than 95,000 admitted patients in 2014. Malcolm Baldrige National Quality Award recipient.	Had a homegrown system. Implemented an integrated EHR system in 2012 in a big bang approach
P4	Vice President of Clinical Information, primary role is to understand and prioritise physician requests to update the electronic medical record for inpatient applications, a physician	Not-for-profit, integrated health system including 12 hospitals and 250 plus sites of care. Six hospitals Magnet® status	Implemented an integrated EHR in 2003. HIMSS Davies Organisational Award
P5	Chief Health Informatics Officer, responsible for enterprise-wide systems regarding strategically planning and supporting the facilities using information technology and the health IT, a nurse executive	A division of a national health system in the Northwest region. It includes eight medical centres with 1601 beds and 51 outpatient clinics and facilities. Had over 3.44 million patient visits in 2014	Implemented an integrated EHR system 1998–2000. Implemented a clinical information system used in ICU's in 2010. HIMSS Davies Organisational Award
P6	Director of IS & Clinical Informatics, responsible for overall adoption, implementation and support of the EHR, a nurse executive	Not-for-profit, integrated health system including five hospitals with over 24,600 admissions in 2014	Ambulatory EMR in 2003, $140 M Inpatient EHR Implemented 2007–2008. Go-live of two more hospitals in 2010 and 2012–2013. HIMSS Davies Organisational Award
P7	Assistant Chief Medical Information Officer, a core team responsible for reviewing and approving changes/content within the EHR; a health information management sub-committee member, a physician lead, an urologist	A public 730-bed teaching hospital with more than 32,000 annual admissions. Nationally ranked in seven specialities in Best Hospitals by the U.S. News & World Report 2015–2016	Implemented an integrated EHR in 2009. HIMSS Enterprise Davies Award
P8.1	Informatics Nurse	Same organisation. Not-for-profit integrated health system with 70 facilities including three hospitals. It serves more than 1.2 million patients annually. Recipient of Malcolm Baldrige Award. Magnet recognition from the American Nurses Credentialing Centre 2014	Implemented ambulatory EHR in 2007 and inpatient in 2011 (same integrated EHR)
P8.2	System Analyst Supervisor supervising all the clinical applications for inpatient and outpatient EHR.		
P8.3	Analyst for inpatient applications, a nurse		
P8.4	Analyst trainee for inpatient applications, a nurse		
P9	Associate Chief Medical Officer of Innovation, optimised an EMR system for about 12 years, a physician	Integrated health system, here outpatient focus as a hospital group, the medical group was merged by a large hospital group in 2014	Implemented inpatient EHR 2001. Different vendor ambulatory EHR in 2014 after merger
P10	Director of Clinical Informatics and EHR Optimisation, helps IT to prioritise optimisation and responsible for building clinical applications	Not-for-profit health care system including eight hospitals with more than 168,000 admissions in 2013. Ranked nationally by U.S. News & World Report, with 10 specialities	Implemented an integrated EHR in 2007–2010
P11	Director Health System Informatics, responsible for all of the training and end-user optimisation work with regard to EMR end users	Academic medical centre with more than 900 beds. 'America's Best' by U.S. News & World Report in 11 specialities in 2010, Nursing Magnet status	Ambulatory EMR in 2008, implemented an integrated inpatient EHR in 2011. HIMSS Stage 7
P12	Director of Information Technology, served as Optimisation Manager	Top 50 in 2015–16 America's Best Hospitals rankings in U.S. News & World Report, Quest for Quality award by the American Hospital Association. Magnet® status 2009	$237 M EMR project approved in 2005 – the largest and most complex project. Implemented an integrated EHR in 2007–2008. HIMSS Davies Enterprise/ Organisational Award

ICU = intensive care unit.

And it's very strange. My workload now is ... it's actually a lot more than it used to be ... I have a lot more on my plate now than I did during implementation ... it is exponentially more work to do optimisation than it is in implementation (P2).

Importance of prioritisation emerged

Participants recognised the importance of prioritising requests. Due to limited resources and staff, information services (IS) had to prioritise the requests to address the most important ones. In this prioritisation, a committee or advisory group that was multidisciplinary with representatives from various departments (*e.g.* medical staff and nursing) played a key role. A participant said, '*Optimisation really is about prioritising top best usual resources to improve your system. That's the hardest part*' (P2).

The committee or advisory group not only determined prioritisation but also oversaw all system-wide changes that affected everybody within the EHR system. After a comprehensive review, the committee approved a solution, suggested a revision of a solution or recommended further investigation of an issue or request. They prioritised requests according to common fundamental principles: safety, efficiency, return on investment (ROI), quality, regulatory requirements and process improvements, listed in the order of the most cited.

In addition to the central governance committee, forming a workgroup, team or sub-committee started the optimisation processes. These groups were a taskforce that carried out an optimisation project in support of the central committee. For example, one participant established a team to improve inefficient nursing charting (P5). Two sites had an official optimisation team, while others did not. The optimisation teams consisted of directors or managers, clinical informaticists, EHR application analysts and process improvement personnel (P10 and P12).

Predominant focus on improving efficiency of EHR

Improving efficiency of EHR was the predominant focus of optimisation processes. Out of 24 identified optimisation processes, the collective effort in increasing efficiency of EHR systems appeared most frequently, in a rate of 25.0% as shown in Table 2.

Table 2 Optimisation processes

Order	Optimisation Processes	Coded	Frequency** (%)
	Optimisation processes – Increasing efficiency [COLLECTIVELY]*	**138**	**25.0**
1	a) Optimisation processes – Increasing efficiency – General	43	7.8
2	b) Optimisation processes – Increasing efficiency – Making workflow more efficient	37	6.7
3	c) Optimisation processes – Optimising practice/process/workflow	27	4.9
4	d) Optimisation processes – Increasing efficiency – Minimising time with EHR	19	3.4
5	e) Optimisation processes – Increasing efficiency – Right data at right time	12	2.2
6	Optimisation processes – Prioritising/validating requests/identifying requests and opportunities	53	9.6
	Optimisation processes – Adoption to standardisation [COLLECTIVELY]*	**53**	**9.6**
7	a) Optimisation processes – Adoption to standardisation	44	8.0
8	b) Optimisation processes – Adoption to standardisation – Standardising physician ordering	9	1.6
	Optimisation processes – Smarter decision support [COLLECTIVELY]*	**45**	**8.2**
9	a) Optimisation processes – Smarter decision support	35	6.3
10	b) Optimisation processes – Smarter decision support – Outcome-focused by driving actual intervention, not simple alerts	10	1.8
11	Optimisation processes – Forming committees/teams/groups	43	7.8
12	Optimisation processes – Improving patient care quality	33	6.0
13	Optimisation processes – Realising ROI, value, cost-savings	29	5.3
14	Optimisation processes – Effectively tracking metrics	22	4.0
15	Optimisation processes – Improving outcomes	21	3.8
16	Optimisation processes – Increasing safety	20	3.6
17	Optimisation processes – Using data in EHR	20	3.6
18	Optimisation processes – Meeting regulatory requirements	17	3.1
19	Optimisation processes – Improving documentation	14	2.5
20	Optimisation processes – Upgrade and implementing/building new features/modules	14	2.5
21	Optimisation processes – Stabilising the implemented EHR	10	1.8
22	Optimisation processes – Getting to/Maximising 'model' or 'foundation' system	7	1.3
23	Optimisation processes – Thoughtful change management	7	1.3
24	Optimisation processes – Improving physician/end-user adoption of EHR	6	1.1
	Total codes = 24	552	100.0

*[COLLECTIVELY] was added to aggregate similar codes for analysis purpose only. It was not an actual code.

**Frequency (%) of observed theme based on coded time (*e.g.* increasing efficiency – General appears 7.8% out of the processes).

Standardisation

Standardisation was a common theme. Standardising workflows, processes and policies across the organisation was one typical part of the optimisation process. There were two types of standardisation. A top-down approach was a system-wide implementation of optimisation that was approved by the central committee. A bottom-up approach was the opposite. It started at a local facility and was proven with positive results. Then, this optimisation was escalated to the central committee for approval and subsequently, disseminated throughout the integrated health system, even to a national level.

> *we want to make certain that the guiding principles say any build work that we do and the optimisations that we do, ensure that we have the gold standard across the organisation (P6).*

Standardisation required thoughtful change management. '*You get this [change] because you have to have it and you have to prove to us why you have to have it*', said a participant (P2). In addition, there was a local level of standardisation described in a surgery supply optimisation project (P12). It was not an enterprise undertaking, but it standardised how the physicians chose surgery supplies that was previously driven by their preferences. The team unified multiple suppliers into one for cost containment.

Optimisation timing

In general, optimisation did not happen immediately after the go-live date. One participant said, '*Once you get something that works, then you actually start to talk about optimisation*' (P7). However, one site began optimisation even before the go-live date. Because of the considerable investment required for the EHR system, the site made an intentional effort to help realise its full potential and the optimisation yielded great results (P12).

Types of optimisation

There were a total of 16 types (or goals) of optimisation, as summarised in Table 3. An optimisation effort often belonged

Table 3 Types of optimisation

Order	Types of optimisation	Definition or Example	Coded	Frequency (%)*
1	Increasing efficiency	Had four categories: 1) General; 2) Making workflow more efficient; 3) Minimising time spent with EHR and 4) Presenting right data at right time during the care (*e.g.* showing potassium lab results and renal function when a physician places a potassium order)	111	27.5
2	Smarter decision support	Refining clinical reminders, integrated in workflow, outcome-focused	45	11.2
3	Improving patient care quality	For example, decreasing sepsis mortality by building a MEWS system within an EHR system	33	8.2
4	Realising ROI, value, cost-savings	Efforts maximising benefits of EHR systems in financial perspective	29	7.2
5	Optimising practice/process/workflow	Process improvement, for example, improving business process of getting payers' authorisation for expensive imaging studies, thus, reducing denials and consequently, increasing revenue and satisfaction among all stakeholders	27	6.7
6	Effectively tracking metrics	For example, tracking ED patient flow metrics	22	5.5
7	Improving outcomes	For example, ensuring foot exam for diabetic patients	21	5.2
8	Increasing patient safety	For example, screening allergies and drug–drug interactions	20	5.0
9	Using data in EHR	Using reporting function, business intelligence and analytics, research	20	5.0
10	Meeting regulatory requirements	Joint Commission, Meaningful Use, etc.	17	4.2
11	Improving documentation	Reducing/refining templates, simplifying nursing flow sheets	14	3.5
12	Upgrading and implementing/building new features/modules	For example, implementing anaesthesia application after going live with an operation room system	14	3.5
13	Stabilising the implemented EHR	Ensuring stable and reliable function of EHR	10	2.5
14	Maximising 'model' or 'foundation' system	A vendor-specific term, meaning utilising vendor-provided basic system as much as possible	7	1.7
15	Thoughtful change management	Controlling and coordinating change in EHR	7	1.7
16	Improving physician/user adoption of EHR	Driving adoption of EHR specifically among physicians and clinicians	6	1.5
	Total = 16		403	100

to multiple categories. For example, simplifying a complex nursing flow sheet was categorised as increasing efficiency, improving quality of documentation and improving user satisfaction. The most dominant type of optimisation was increasing efficiency. Increasing efficiency had four sub-categories: making workflow more efficient, minimising time spent with EHR, presenting the right information at the right time during care and general efficiency that did not fit the other three subgroups.

> *Efficiency is our biggest priority, you know … making things easier for the providers, for the nurses, to be able to do it themselves in an efficient and effective manner so that they can still see the patients the volume that they've always seen and still give good patient care ... (P8.2).*

The efforts realised measurable benefits in the participants' sites. The participants reported achieving outcomes such as reduced physician's time spent in the EHR by approximately 1 minute per patient (P4); decreased turnaround time by 37% for the emergency department (ED) door to physician and total ED waiting time by 44% for patients being admitted (P12) and cost savings of over half-a-million dollars per year due to reduction in imaging study denials (P9). Such benefits were realised due to other factors as well as process improvement.

Smarter decision support was the second most common type of optimisation. Participant sites improved the way they utilised decision support. The EHR system did not merely trigger alerts. The EHR helped clinicians by integrating refined decision support into the clinician's workflow, not as a 'noise' or interruption but as an effective reminder (P4).

> *So, we want the right information be provided at the point of care … we can build an efficient reminder that has all the information but only the information they need to make effective decision at the time of satisfying the reminder (P5).*

Achieving clinical outcomes was one of the goals for EHR decision support. One participant's site was optimising a diabetic foot exam workflow (P5). A careful investigation of one facility that had a substantial decrease in the number of foot amputations related to diabetic pressure injuries revealed that the facility did not have an alert triggered by clinical decision support. Instead, the facility had a specific practice – taking socks off of the known diabetic patients – that signalled providers to examine the patient's foot. Their experience provided a perspective to think about triggering alerts in the EHR. In this case, firing an alert to remind clinicians to perform the exam had already proven ineffective, whereas the physical signal (removing the socks) integrated into the clinical workflow and achieved the desired outcome (doing foot exam).

> *You want to get closer and closer to the not developed foot ulcer that means examine the foot and it was practice changing in the clinic that actually fits the outcome … it was the actual practice that fixed the outcome (P5).*

The third most common type of optimisation was improving quality of care. As noted above, this was related to other efforts such as increasing safety or efficiency. Some examples were decreasing sepsis mortality by building a system of the Modified Early Warning Score (MEWS) within the EHR (P6) and better identifying of patients with malnutrition by improving dietary information exchange between dieticians and clinicians (P7).

Fourth, there were efforts to realise ROI, value and cost-savings in some organisations. They were strong drivers and decision factors to prioritise optimisation projects (P6). These initiatives were typically an organisation-wide committed effort that utilised the EHR as a '*catalyst*' (P12).

> *Our actual benefit was just shy of 35 million [dollars], and that was a direct result of the optimisation projects ... we exceeded our benefits by almost 20 million dollars in the first year which was a huge, huge accomplishment. Still very, you know, exciting to think about (P12).*

Fifth, there was an effort to optimise practice, process or workflow. The goal was optimising workflows, patient experiences or business processes by leveraging an EHR. '*So it is one thing to say electronic medical record (EMR)/EHR optimisation, but it's really much bigger than that. We're talking about optimising the performance of an organisation, using an EHR as a tool, a catalyst*', said a participant (P12). For example, one site optimised the process of obtaining approval for imaging studies from payers that resulted in significant reduction in denials and consequently, increased revenue and satisfaction among all stakeholders (P9). The remaining optimisation types are summarised in Table 3.

Results of optimisation efforts

Optimisation initiatives generated positive and productive proceeds such as improved productivity and exceeding financial return. Table 4 summarises 16 results of optimisation efforts. The participants perceived realising ROI, cost-savings and value as the most tangible outcome of optimisation, followed by improved quality of care and enhanced efficiency. Improved efficiency was not the top perceived result although it was the predominant type of optimisation. Each result was not necessarily a direct output of only one effort. An optimisation effort yielded multiple benefits, and they were interdependent by nature.

Barriers to optimisation

Table 5 summarises 11 barriers to optimisation noted in this study. The participants indicated that resistance to change was the biggest barrier. '*It's always people [Laugh] – people who don't want to change, people who believe they already do things the best way they can…It wasn't the systems. It wasn't the leadership as much as it was the staff nurse or the anaesthesiologist who just refused to change*', confessed a participant (P12). Resistance to change was mitigated by getting operation's support or engaging key stakeholders from the beginning of optimisation projects. These were actually identified as two facilitators to optimisation. Engaging leadership and operations staff, clinicians and users was a key to overcoming the resistance to change barrier. The second

Table 4 Results of optimisation

Order	Results of optimisation	Definition or Example	Coded	Frequency (%)
1	Realised ROI, value, cost savings	Realising substantial financial returns by utilising EHR (*e.g.* optimising and standardising physicians' surgical supply selection process, resulting significant benefits), also included cost avoidance (*e.g.* preventing hospital admissions, decreasing reimbursement denials by payors)	38	18.1
2	Improved quality of care	For example, early sepsis recognition by utilising a MEWS built in the EHR system	32	15.2
3	Improved efficiency	For example, more standardised note templates, order sets, streamlined workflow within the EHR system, less mouse clicks required	27	12.9
4	Improved safety	For example, decreased mortality rate	26	12.4
5	Improved clinical outcome	For example, decreased number of amputation for diabetic patients by optimising foot assessment workflow in clinics	18	8.6
6	Increased end-user/physician satisfaction	For example, due to less time spent in EHR and reduced burden of documentation	16	7.6
7	Capturing more core measure reporting	For example, maintaining certification such a stroke centre, trauma centre or earning quality recognition such as nursing Magnet status	12	5.7
8	Improved practice/process/workflow	For example, improved ED patient flow by using EHR data as metrics	10	4.8
9	Improved documentation/charting	For example, key nursing documentation is more captured after reducing number of flow sheet rows and organising them to drive better quality of documentation	8	3.8
10	Increased patient satisfaction	For example, by the reduced waiting time in ED	6	2.9
11	Improved EHR system	Improving overall functions and reliability of the system	5	2.4
12	Improved compliance to best practice	For example, increased number of orders for venous thromboembolism prophylaxis	3	1.4
13	Improved collaboration	Among clinicians	3	1.4
14	Reduced burden of documentation	For example, substantially leaned and refined nursing flow sheets documentation	2	1.0
15	Less training required	Due to streamlined workflow and intuitive system	2	1.0
16	Improved usability	For example, easier to place orders, easier to find information	2	1.0
	Total = 16		210	100

barrier was limited resources, in particular, because IS was not a 'revenue-generating' department (P6). It was difficult for the IT department to justify increasing resources after a massive EHR implementation that itself required significant resources. Furthermore, a typical request-based allocation of resources added more strain because optimisation did not necessarily require an immediate fix that resulted in low priority on resource allocation. The third barrier was a bureaucratic process that often included multiple layers of approval. Bureaucratic processes were long and arduous and typically reduced agility and efficiency in optimising the EHR (P9). The remaining barriers are summarised in Table 5.

Facilitators to optimisation

Table 5 summarises 20 facilitators to optimisation that were identified in this study. Overwhelmingly, the participants recognised *dedicated* resources for optimisation as the biggest facilitator. A *dedicated* resource did not necessarily mean an additional resource. It was rather a 'commitment' to the optimisation as evidenced by allocating staff/resources/time or forming a team to work on optimisation projects (P10). Dedicating resources was the single most effective facilitator for optimisation.

> *What I love about what we had done in the past is… we had a small enough team, I should say a dedicated team to our group [organisation]… And that really worked well, and I worked closely with them and we trusted each other and we got a lot of stuff done* (P9).

Advisory groups, teams or committees that carried out or oversaw optimisation were the second biggest facilitator. These teams facilitated optimisation by performing an optimisation initiative, helping prioritisation and allocation of resources, bridging IT and operations or making system-wide decisions for change. They were 'the foundation' of a successful optimisation (P3). The groups met on a regular basis, and having regular meetings was another facilitator of optimisation.

Table 5 Barriers and facilitators to optimisation

	Order	Definition	Coded	Frequency (%)
Barriers	1	People, resistance to change	17	23.9
	2	Limited resources	11	15.5
	3	Bureaucratic process and/or multiple layers of approval	10	14.1
	4	Poor communication/poor channel to connect IT/IS	10	14.1
	5	Lack of standardised practice/process/policies	7	9.9
	6	Time – too busy people/everybody calling highest priority	6	8.5
	7	Difficulty in reaching consensus among stakeholders, competing interests	4	5.6
	8	Lack of coordination between requests	2	2.8
	9	Technically not possible to make it happen	2	2.8
	10	Complexity of EHR	1	1.4
	11	Misunderstanding optimisation as a sole IT project	1	1.4
Facilitators	1	Dedicated resources, commitment	49	13.0
	2	Advisory councils/groups/executive committees	47	12.5
	3	Connection with users & business owners face-to-face or indirectly	43	11.4
	4	Informatics people	39	10.4
	5	Engagement – super users, end users, physicians	33	8.8
	6	Engagement – operation/leadership	25	6.6
	7	Regular meetings	25	6.6
	8	Supportive leadership/management	19	5.1
	9	Aligning optimisation with the organisation's goals/strategies	18	4.8
	10	Identifying champions	14	3.7
	11	Training/learning/education	13	3.5
	12	Usability test	12	3.2
	13	User's needs	10	2.7
	14	Process improvement	9	2.4
	15	Demonstrating value in optimisation	7	1.9
	16	ROI	5	1.3
	17	Good timeline to implement/test/train, not rushing	2	0.5
	18	Culture of organisation driving improvement	2	0.5
	19	Organisational change (*e.g.* leadership change)	2	0.5
	20	Regulatory requirements/changes	2	0.5

Interacting with users and business owners played an important role in optimisation and was the third most common facilitator. This connection between end users or operations and the IT team was essential for successful optimisation efforts. It helped the IT department to understand users' issues and their actual workflows. The optimisation people conducted regular user-developer conferences, meetings, conversations or observed users and business owners. Based on common ground, they collaborated to develop a solution that received a wide and effortless adoption among end users.

> *I think the big key is we left IT and corporate and we lived in the hospital. And that was I think the biggest and it's biggest for me. I think it's what made us the most successful (P12).*

Informatics professionals who connected IT to clinicians and operations were the fourth facilitator. One informatics nurse said, '*Specifically, I'm kind of the communication conduit… I'm kind of the conduit for requests and changes and needs*' (P8.1). The remaining facilitators are listed in Table 5.

DISCUSSION

The main finding of this study was recognising the importance of optimisation following, and even before, implementation of EHR systems. We found there were overflowing requests largely related to increasing efficiency of EHR after implementation. This need to make EHR more efficient and usable is real, as evidenced by failing design and usability of implemented EHR systems.[17–20] Improvement does not necessarily follow implementation, contrary to an assumption that a smooth go-live will automatically make clinicians' jobs easier and subsequently improve clinical outcomes.[10,21–24] To some extent, there are immediate benefits after implementation, but in practice, it takes an effort of cultivation to ensure such promised results are actually realised.[9–12,25,26] Optimisation is a *hallmark* of successful implementation as McAlearney *et al.*[2] discovered. From the evaluation standpoint, in accordance with Hadji *et al.*,[27] this refinement of the system by optimisation becomes a major determinant of user satisfaction.

The diffusion of innovation theory by Rogers[28] is commonly used as a framework to study adoption of innovations related to information technology. According to this theory, there are four main determinants of success of an innovation: communication channels, the attributes of the innovation, the characteristics of the adopters and the social system. In our findings, we see that some respondents would be considered 'early adopters' of the optimisation approach (the innovation in this context); an organisation had started the optimisation process even before their EHR implementation phase. The EHR system was the largest financial investment this organisation had made, and ROI was a significant driver in adopting the optimisation approach as early as possible. The 'relative advantage' of the optimisation, namely the degree to which an organisation perceives benefits by adopting the innovation, is one of the user-perceived qualities that define an innovation and can affect adoption.[28] In this case, the expectation of and commitment to anticipated benefits led to early adoption of optimisation. As Moore and Benbasat[29] point out, the more an innovation can address the needs and expectations of potential adopters, the greater the likelihood for adoption. Our findings demonstrate that organisational commitment to maximising benefits from the implementation of an EMR may indeed affect the timing and extent of optimisation efforts.

Second, the present study highlighted the importance of dedicating resources *solely for optimisation*, validating Cooley *et al*.[30] request not to underestimate the resources necessary to support computerised physician order entry after implementation. Dedicated resources were the biggest facilitator and the second biggest barrier to optimisation. The participant organisations that devoted resources exclusively to optimisation had seen great returns. Cost of dedicating resources was relatively small in comparison to a typical huge investment in implementation. It was largely cost of human resources – a team of about five experts. After go-live, organisations tend to be occupied with maintenance requests, '*putting out fires all the time*', thereby consuming most of their limited resources (P9). These types of requests are usually urgent because something is broken, but they are not necessarily the most important from an organisational standpoint. Even if there is attention to optimisation, it may not be optimal because in the end, the same people work both in the maintenance and optimisation. The staff may experience divided attention and burnout. In order to move optimisation opportunities to the next level, dedicating resources and staff are required. Optimisation should ideally be separated from maintenance and support of EHR.

Third, this study found there are barriers and facilitators specific to optimisation. Most of the identified barriers and facilitators, for example, resistance to change,[31,32] engaging leadership and end users,[33,34] importance of informatics professionals[33,35] and interdisciplinary committees[30] are well documented in many studies.[30,32–34,36–41] Despite this overlap, we uncovered additional barriers unique to optimisation such as a bureaucratic process requiring multiple layers of approval for change, poor communication and lack of standardisation. We also appreciated and highlighted those documented success factors in the optimisation perspective, particularly regarding dedicating resources.

Fourth, this study revealed an outcomes-driven approach to clinical decision support. Drawing from the insight of a participant's experience, clinical decision support should drive actual clinical outcomes (P5). Conventionally, clinical decision support consists of triggering many alerts and sometimes hard-stops, which interrupt the workflow of clinicians and cause alert fatigue. Mandated hard-stops dictate what clinicians should do, leaving them feeling less autonomous and dissatisfied. The ultimate goal is to ensure that clinical care is delivered at the right time, not just reminding clinicians of doing it. Actual clinical intervention, not a reminder, is the closest proxy to a desired clinical outcome. Busy and hard-working clinicians are drowning in a flood of useless alerts. Alerts should be refined and wisely integrated into the clinician's workflow to drive actual intervention.

Fifth, this study provided insights on defining EHR optimisation. Participants recognised optimisation as an ongoing process improving EHR systems. We noted there were two different approaches to optimisation. One was user-driven. Starting from issues or requests, it continually brought refinement and enhancement to the system, thus, making it more useful and efficient. The second was organisation-driven; it was an organisational project, not an IT project. It was truly about optimising processes, practices, workflows and performance of the organisation by leveraging the implemented EHR system. It was an intentional commitment to realise actual benefits of the EHR implementation. This finding is comparable to a conceptual understanding of EHR optimisation noted in the literature in the absence of any direct definition.[3,42] Blavin *et al*.[42] recognise EHR optimisation as 'continually modifying technology for optimal use as better able to use technology to meet an organisation's performance goals' in a comprehensive literature review. Blavin *et al*.[42] acknowledge optimisation as one of four distinct stages of the EHR implementation process, which are 'planning and vendor selection' (acquisition), 'workflow and software design' (implementation), 'training and user support' (implementation) and '*optimisation and modification*'. Notably, Blavin *et al*.[42] discovered a need to examine EHR optimisation with emphasis on outcomes. Drawing from the findings from the study and literature, optimisation of EHR should be defined as an ongoing commitment with dedicated resources to improve the EHR system and realise its benefits to the fullest by achieving measurable outcomes both after and before implementation.

Lastly, this study validated findings of prior studies. There was dissatisfaction among clinicians following EHR implementation. The decreased productivity, burden of documentation, sensory and cognitive overload and increased time required to get things done in EHR systems contributed collectively to clinicians' widespread dissatisfaction and frustration over EHR systems.[5,43–45] The reduced productivity was consistent with previous findings.[46,47]

The study findings present numerous implications. Recognising a strong demand to improve efficiency of EHR systems as evidenced by surging requests, the healthcare organisations planning on, in the midst of implementation or post go-live should allocate adequate resources to optimisation. Despite limited resources, even small healthcare organisations could still make an intentional commitment to optimisation

within their capacity. Ideally, a dedicated optimisation team should be established. The organisations should also cultivate an optimisation-friendly environment by eliminating or mitigating the barriers to optimisation while promoting the facilitators. Additionally, during the design and implementation phase, they should ensure more robust engagement of clinicians (*e.g.* usability test, seeking clinicians' iterated feedback on EHR system design) to incorporate the clinicians' optimal workflows and insights into development of EHR system which will result in more refined system. Finally, an evaluation system measuring actual outcomes of optimisation and implementation should be established and employed. Making the EHR system 'go-live' is just the beginning. Real success of EHR implementation or optimisation must be measured by its realised benefits.

This study has limitations to consider. First, the collected data may not fully represent the participant organisations' perspectives, because most organisations were represented by a single participant. Additionally, a 1-hour interview may not be enough time to capture the full experience of a large organisation. However, strong efforts were made to mitigate this risk by referring to publicly available information (*e.g.* HIMSS Davies Award applications) for validation of findings. Second, a single researcher completed the study interviews, transcriptions and large part of coding and analyses due to inadequate resources, thus, possibly introducing a personal bias and violating the best practice in qualitative research. In order to overcome this limitation, a rigorous study methodology was designed and followed and there was regular frequent discussion among the research team throughout the study. During the coding and data analysis, other team members reviewed the coding, refined development of the complete coding guide and data analysis framework and validated data analysis and interpretation. The team's detailed involvement is documented in Authors' Contributions. Third, the sample size is small (N = 15) with a low response rate (20 respondents out of 997 contacted individuals). Although we could recruit more participants with follow-up invitations or phone calls, we intentionally did not pursue it due to practical considerations and also, considering the qualitative nature of the study and the fact that data saturation was reached. Expanding sample size was not feasible, for this study was carried out under very limited resources. Lastly, the research team did not include patients and caregivers who would be an ultimate recipient of EHR optimisation benefits.

Future research should focus on measuring the impact of optimisation on clinical outcomes. This study was not designed to identify a concrete connection between optimisation efforts and actual clinical outcomes for the patient. This is one area that needs improvement and further study.[12]

CONCLUSION

This study describes experiences of optimising EHRs in select high performing healthcare organisations in the US. Optimisation included prioritising exponentially increasing requests, focus on improving efficiency of EHR, standardisation and forming teams and advisory groups to guide optimisation processes. Sixteen types of interdependent optimisation efforts were identified and discussed as well as barriers and facilitators to optimisation. These results highlighted the importance of optimising EHR after, and in some instances before, go-live and dedicating resources exclusively for optimisation. We found that optimisation means more than improving an EHR system; it also includes the optimisation of workflows, processes, practices and performance of the organisation by leveraging EHR as a 'catalyst'.

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Competing Interests

The authors declare they have no conflicts of interest in the research.

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Authors' Contributions

Mark Chun Moon conceived and designed the study, recruited study participants, collected data, performed data analysis, drafted and revised manuscript. Rebecca Hills refined the study design, reviewed the Interview Guide, the coding guide and the coding, data analysis and revised a significant portion of manuscript. George Demiris supervised overall conduction of the research, reviewed and approved the study design, sampling, data acquisition, analysis and interpretation and revised a significant portion of manuscript.

REFERENCES

1. McAlearney AS, Sieck C, Hefner J, Robbins J and Huerta TR. Facilitating ambulatory electronic health record system implementation: evidence from a qualitative study. *BioMed Research International* 2013;2013:629574.
2. McAlearney AS, Song PH, Robbins J, Hirsch A, Jorina M, Kowalczyk N, *et al*. Moving from good to great in ambulatory electronic health record implementation. *Journal for Healthcare Quality* 2010;32(5):41–50. Available from: https://doi.org/10.1111/j.1945-1474.2010.00107.x.
3. Pandhi N, Yang W-L, Karp Z, Young A, Beasley JW, Kraft S, *et al*. Approaches and challenges to optimising primary care teams' electronic health record usage. *Informatics in Primary Care* 2014;21(3):142–51. Available from: https://doi.org/10.14236/jhi.v21i3.57.
4. Ash JS, Berg M and Coiera E. Some unintended consequences of information technology in health care: the nature of patient care information system-related errors. *Journal of the American Medical Informatics Association*

2004;11(2):104–12. Available from: https://doi.org/10.1197/jamia.M1471. PMid:14633936; PMCid:PMC353015.

5. Campbell EM, Sittig DF, Ash JS, Guappone KP and Dykstra RH. Types of unintended consequences related to computerized provider order entry. *Journal of the American Medical Informatics Association* 2006;13(5):547–56. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1561794/; https://doi.org/10.1197/jamia.M2042. PMid:16799128; PMCid:PMC1561794.
6. Ash JS, Sittig DF, Poon EG, Guappone K, Campbell E and Dykstra RH. The extent and importance of unintended consequences related to computerized provider order entry. *Journal of the American Medical Informatics Association* 2007;14(4):415. Available from: https://doi.org/10.1197/jamia.M2373. PMid:17460127; PMCid:PMC2244906.
7. Leventhal R. Trend: EHR optimization. Post-implementation advancements. Leaders from various healthcare organizations explain how they have been moving forward with their EHRs following implementation. *Healthcare Informatics* 2014;31(2):30. Available from: https://www.ncbi.nlm.nih.gov/pubmed/24812989. PMid:24812989.
8. Terry K. Rev up your EHR: how to optimize performance: learn ways to increase revenue, improve practice efficiency and quality. *Medical Economics* 2011;88(22):S4.
9. Baron RJ. Quality improvement with an electronic health record: achievable, but not automatic. *Annals of Internal Medicine* 2007;147:549–52. Available from: www.annals.org. Available from: https://doi.org/10.7326/0003-4819-147-8-200710160-00007. PMid:17938393.
10. Desroches CM, Campbell EG, Vogeli C, Zheng J, Rao SR, Shields AE, *et al*. Electronic health records' limited successes suggest more targeted uses. *Health Affairs* 2010;29(4):639. Available from: https://doi.org/10.1377/hlthaff.2009.1086. PMid:20368593.
11. Ryan A, Bishop T, Shih S and Casalino L. Small physician practices in New York needed sustained help to realize gains in quality from use of electronic health records. *Health Affairs* 2013;32(1):53–62. Available from: https://doi.org/10.1377/hlthaff.2012.0742. PMid:23297271; PMCid:PMC3864096.
12. Spetz J, Burgess JF and Phibbs CS. The effect of health information technology implementation in Veterans Health Administration hospitals on patient outcomes. *Healthcare* 2014;2(1):40–7. Available from: http://www.sciencedirect.com/science/article/pii/S2213076414000062. Accessed 12 December 2015.
13. Adler-Milstein J, DesRoches CM, Kralovec P, Foster G, Worzala C, Charles D, *et al*. Electronic health record adoption in US hospitals: progress continues, but challenges persist. *Health Affairs* 2015;34(12):2174–80. Available from: http://content.healthaffairs.org/content/34/12/2174.abstract; https://doi.org/10.1377/hlthaff.2015.0992. PMid:26561387.
14. Charles D, Gabriel M and Furukawa MF. Adoption of electronic health record systems among U.S . Non-federal acute care hospitals : 2008–2013 [Internet]. 2014. Available from: http://www.healthit.gov/sites/default/files/oncdatabrief16.pdf. Accessed 20 November 2015.
15. The Office of the National Coordinator for Health Information Technology (ONC). Office of the Secretary USD of H and HS. *Report to Congress: Update on Adoption of Health Information Technology and Related Efforts to Facilitate the Electronic Use and Exchange of Health Information* [Internet]. Vol. 3001. 2014. Available from: http://www.healthit.gov/sites/default/files/rtc_adoption_and_exchange9302014.pdf. Accessed 20 November 2015.
16. Strauss AL and Corbin JM. *Basics of Qualitative Research : Techniques and Procedures for Developing Grounded Theory*. Thousand Oaks, CA: Sage Publications, 1998.
17. Chan J, Shojania KG, Easty AC and Etchells EE. Does user-centred design affect the efficiency, usability and safety of CPOE order sets? *Journal of the American Medical Informatics Association* 2011;18(3):276–81. Available from: https://academic.oup.com/jamia/article-lookup/doi/10.1136/amiajnl-2010-000026; https://doi.org/10.1136/amiajnl-2010-000026. PMid:21486886; PMCid:PMC3078654.
18. Lambooij MS and Koster F. How organizational escalation prevention potential affects success of implementation of innovations: electronic medical records in hospitals. *Implementation Science* 2015;11(1):75. Available from: http://implementationscience.biomedcentral.com/articles/10.1186/s13012-016-0435-1; https://doi.org/10.1186/s13012-016-0435-1. PMid:27206920; PMCid:PMC4875635.
19. Khajouei R and Jaspers MWM. The impact of CPOE medication systems' design aspects on usability, workflow and medication orders a systematic review. *Methods of Information in Medicine* 2010;49:3–19. PMid:19582333.
20. Chan J, Shojania KG, Easty AC and Etchells EE. Usability evaluation of order sets in a computerised provider order entry system. *BMJ Quality & Safety* 2011;20(11):932–40. Available from: http://qualitysafety.bmj.com/lookup/doi/10.1136/bmjqs.2010.050021; https://doi.org/10.1136/bmjqs.2010.050021. PMid:21807652.
21. Agha L. The effects of health information technology on the costs and quality of medical care. *Journal of Health Economics* 2014;34:19–30. Available from: http://www.sciencedirect.com/science/article/pii/S0167629613001720. Accessed 20 November 2015.
22. Hahn K, Ohman-Strickland P, Cohen D, Piasecki A, Crosson J, Clark E, *et al*. Electronic medical records are not associated with improved documentation in community primary care practices. *American Journal of Medical Quality* 2011;26(4):272–7. Available from: https://doi.org/10.1177/1062860610392365. PMid:21266596; PMCid:PMC3137715.
23. Huntington MK and Shafer CW. EHR implementation adversely affects performance on process quality measures in a community health center. *American Journal of Medical Quality* 2010;25(5):404–5. Available from: http://www.ncbi.nlm.nih.gov/pubmed/20833986. Accessed 26 July 2014.
24. Zhou L, Soran CS, Jenter CA, Volk LA, Orav EJ, Bates DW, *et al*. The relationship between electronic health record use and quality of care over time. *Journal of the American Medical Informatics Association* 2009;16(4):457–64. Available from: http://jamia.oxfordjournals.org/content/16/4/457.abstract; https://doi.org/10.1197/jamia.M3128. PMid:19390094; PMCid:PMC2705247.
25. Price M, Singer A and Kim J. Adopting electronic medical records: are they just electronic paper records? *Canadian Family Physician* 2013;59(7):E322. PMid:23851560; PMCid:PMC3710063.

26. Liang LL, Berwick DM and Permanente K. *Connected for Health: Using Electronic Health Records to Transform Care Delivery*. San Francisco, CA: Jossey-Bass, 2010.
27. Hadji B, Martin G, Dupuis I, Campoy E and Degoulet P. 14 Years longitudinal evaluation of clinical information systems acceptance: the HEGP case. *International Journal of Medical Informatics* 2016;86:20–9.
28. Rogers EM and Singhal A. Diffusion of innovations. In: Salwen M, Stacks D (Eds), *An Integrated Approach to Communication Theory and Research*, 5th edition. Mahwah, NJ: LEA, 2003, pp. 409–19.
29. Moore GC and Benbasat I. Development of an instrument to measure the perceptions of adopting an information technology innovation. *Information Systems Research* 1991;2(3):192–222. Available from: https://doi.org/10.1287/isre.2.3.192.
30. Cooley TW, May D, Alwan M and Sue C. Implementation of computerized prescriber order entry in four academic medical centers. *American Journal of Health-System Pharmacy* 2012;69:2166–73. Available from: https://doi.org/10.2146/ajhp120108. PMid:23230041.
31. Boonstra A, Versluis A and Vos JFJ. Implementing electronic health records in hospitals: a systematic literature review. *BMC Health Services Research* 2014;14(1):370. Available from: http://www.biomedcentral.com/1472-6963/14/370; https://doi.org/10.1186/1472-6963-14-370. PMid:25190184; PMCid:PMC4162964.
32. Poon EG, Blumenthal D, Jaggi T, Honour MM, Bates DW and Kaushal R. Overcoming barriers to adopting and implementing computerized physician order entry systems in US hospitals. *Health Affairs* 2004;23:184–90. Available from: https://doi.org/10.1377/hlthaff.23.4.184.
33. Gellert GA, Hill V, Bruner K, Maciaz G, Saucedo L, Catzoela L, *et al*. Successful implementation of clinical information technology: seven key lessons from CPOE. *Applied Clinical Informatics* 2015;6(4):698–715. Available from: https://doi.org/10.4338/ACI-2015-06-SOA-0067. PMid:26767065; PMCid:PMC4704039.
34. Ovretveit J, Scott T, Rundall TG, Shortell SM and Brommels M. Implementation of electronic medical records in hospitals: two case studies. *Health Policy* 2007;84(2–3):181–90. Available from: http://www.ncbi.nlm.nih.gov/pubmed/17624470; https://doi.org/10.1016/j.healthpol.2007.05.013. PMid:17624470.
35. Ash JS, Stavri PZ, Dykstra R and Fournier L. Implementing computerized physician order entry: the importance of special people. *International Journal of Medical Informatics* 2003;69(2–3):235. Available from: https://doi.org/10.1016/S1386-5056(02)00107-7.
36. Ash JS, Stavri PZ and Kuperman GJ. A consensus statement on considerations for a successful CPOE implementation. *Journal of the American Medical Informatics Association* 2003;10:229–34. Available from: https://doi.org/10.1197/jamia.M1204.
37. McGinn CA, Grenier S, Duplantie J, Shaw N, Sicotte C, Mathieu L, *et al*. Comparison of use groups perspectives of barriers and facilitator to implementing EHR—a systematic review. *BMC Medicine* 2011;9:46. Available from: https://doi.org/10.1186/1741-7015-9-46.
38. Sengstack PP and Gugerty B. CPOE systems: success factors and implementation issues. *Journal of Healthcare Information Management* 2004;18(1):36–45. Available from: http://www.ncbi.nlm.nih.gov/pubmed/14971078. PMid:14971078.
39. Weir C, Lincoln M, Roscoe D, Turner C and Moreshead G. Dimensions associated with successful implementation of a hospital based integrated order entry system. *Proceedings the Annual Symposium on Computer Application [sic] in Medical Care* 1994;653–7. PMid:7950009; PMCid:PMC2247902.
40. Safdari R, Ghazisaeidi M and Jebraeily M. Electronic health records: critical success factors in implementation. *Acta Informatica Medica* 2015;23(2):102–4. Available from: http://www.ncbi.nlm.nih.gov/pubmed/26005276%5Cn; http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC4430004; https://doi.org/10.5455/aim.2015.23.102-104. PMid:26005276; PMCid:PMC4430004.
41. Scott JT, Rundall TG, Vogt TM and Hsu J. Kaiser Permanente's experience of implementing an electronic medical record: a qualitative study. *BMJ* 2005;331:1313–6. Available from: https://doi.org/10.1136/bmj.38638.497477.68.
42. Blavin F, Ramos C, Shah A and Devers K. Lessons from the literature on electronic health record implementation: a study funded by the Office of the National Coordinator for Health Information Technology of the U.S. Department of Health and Human Services [Internet]. 2013. Available from: http://www.healthit.gov/sites/default/files/hit_lessons_learned_lit_review_final_08-01-2013.pdf. Accessed 20 November 2015.
43. American Medical Association. Improving care: priorities to improve electronic health record usability [Internet]. 2014. Available from: https://download.ama-assn.org/resources/doc/ps2/x-pub/ehr-priorities.pdf. Accessed 6 October 2014.
44. Friedberg MW, Chen PG, Van Busum KR, Aunon FM, Pham C, Caloyeras JP, *et al*. *Factors Affecting Physician Professional Satisfaction and Their Implications for Patient Care, Health Systems, and Health Policy* [Internet]. Santa Monica, CA: RAND Corporation, 2013. Available from: http://www.rand.org/pubs/research_reports/RR439.html.
45. Koopman RJ, Steege LMB, Moore JL, Clarke MA, Canfield SM, Kim MS, *et al*. Physician information needs and electronic health records (EHRs): time to reengineer the clinic note. *The Journal of the American Board of Family Medicine* 2015;28(3):316. Available from: https://doi.org/10.3122/jabfm.2015.03.140244. PMid:25957364.
46. Bonner LM, Simons CE, Parker LE, Yano EM and Kirchner JE. "To take care of the patients": qualitative analysis of Veterans Health Administration personnel experiences with a clinical informatics system. *Implementation Science* 2010;5:63. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2931450/; https://doi.org/10.1186/1748-5908-5-63. PMid:20727182; PMCid:PMC2931450.
47. Jamoom EW, Patel V, Furukawa MF and King J. EHR adopters vs. non-adopters: impacts of, barriers to, and federal initiatives for EHR adoption. *Healthcare* 2014;2(1):33–9. Available from: http://www.sciencedirect.com/science/article/pii/S2213076413000845. Accessed 12 December 2015.

APPENDIX A

Understanding optimisation processes of electronic health records in select hospitals

Interview Guide

Date _____

Participant Name _____ Organisation _____

INTRODUCTION

Thank you for participating in this study; I do appreciate your time. I need to give you a little background before asking if you agree to being interviewed. This interview is focused on your experience handling the optimisation of the EHR in your organisation after the system went live. During this interview, I'll ask you questions about your background and position, the EHR implementation, and largely optimisation and your specific experience on post go-live. If you agree, I would like to record this interview; the audio file will be used to help with note taking. All information from this interview will be confidential. Your name will be known only to me. If names come up during the interview they will be removed from my notes to maintain your anonymity and the confidentiality of all information you share. This interview will take approximately 30–60 minutes. You do not need to answer every question. If at any time you wish to stop the interview, please let me know and we will end the session. I appreciate your candid responses to my questions.

Do you agree to being interviewed? *If participant agrees, recorder is turned on.*

Thank you for agreeing to be interviewed.

BACKGROUND

What is your title?
Please describe your role within your organisation.
How long have you been in this position?
What is (was) your role in relation to implementing or supporting and maintaining the EHR system in your organisation?

EHR IMPLEMENTATION

Implementation process

Please describe the overall implementation process of the EHR system in your organisation.

EHR OPTIMISATION

After go-live of the EHR system

What has become your priority regarding the EHR after go-live?
What workload change have you seen?
What are any users or organisational expectations on post go-live?

Definition of EHR optimisation

How would you define EHR optimisation?

EHR optimisation processes

What has your organisation been doing to leverage the implemented EHR system?
What processes or initiatives has your organisation undertaken to improve the quality and efficiency of care or lowering the cost of care with relation to the implemented EHR system?

Analysis of EHR optimisation processes

What results/outcomes has your organisation been seeing through these efforts? Why these results/outcomes are important to your organisation?
What specific roles did the EHR optimisation play to achieve such outcomes/results?

What are the barriers and facilitators you have seen during the EHR optimisation? How has your organisation overcome the barriers? How has your organisation promoted the facilitators?
Who have played key roles for the successful optimisation? Please describe their roles in the EHR optimisation.

Advice for embarking on EHR optimisation

Do you think it is important to plan and execute the EHR optimisation, with dedicated resources, as an integral part of the EHR implementation? If so, why do you think so?
What would you do differently to ensure successful EHR optimisation if you have to do it again?
For those who are embarking on a journey of the EHR optimisation after go-live, what advice would you give to them?

CONCLUSION

Do you have any other concerns, thoughts or recommendations regarding EHR optimisation in your organisation or in general?
Could you recommend any other persons in your organisation, who can best address the questions we just went over?

That was my last question. Thank you for your time. What questions do you have for us?

APPENDIX B

Data analysis framework with codes

Research questions	Codes (110)	Comments
1) What do hospitals do with implemented EHR systems to demonstrate the benefits of the deployed systems and to meaningfully use the systems?	Characteristics post go-live – Clinicians dealing with inefficiency	
	Characteristics post go-live – Clinicians feeling burden of documentation	
	Characteristics post go-live – Cognitive overload for end users	
	Characteristics post go-live – Dissatisfaction of end users	
	Characteristics post go-live – Expectation pre go-live	
	Characteristics post go-live – Experiencing integrated system	
	Characteristics post go-live – Increased time to document	
	Characteristics post go-live – Informatics people workload change	
	Characteristics post go-live – Little/No focus on optimisation	
	Characteristics post go-live – Nurses over-charting/under-charting	
	Characteristics post go-live – Poor documentation	
	Characteristics post go-live – Requests increase exponentially	
	Characteristics post go-live – Working on increasing users' proficiency with EHR	
	Optimisation processes – Adoption to standardisation	
	Optimisation processes – Adoption to standardisation – Standardising physician ordering	
	Optimisation processes – Effectively tracking metrics	
	Optimisation processes – Forming committees/teams/groups	
	Optimisation processes – Getting to/Maximising 'model' or 'foundation' system	
	Optimisation processes – Improving documentation	
	Optimisation processes – Improving outcomes	
	Optimisation processes – Improving patient care quality	
	Optimisation processes – Improving physician/end user adoption of EHR	
	Optimisation processes – Increasing efficiency – General	
	Optimisation processes – Increasing efficiency – Making workflow more efficient	
	Optimisation processes – Increasing efficiency – Minimising time with EHR	

	Optimisation processes – Increasing efficiency – Right data at right time	
	Optimisation processes – Increasing safety	
	Optimisation processes – Meeting regulatory requirements	
	Optimisation processes – Optimising practice/process/workflow	
	Optimisation processes – Prioritising/validating requests/identifying requests & opportunities	
	Optimisation processes – Realising ROI, value, cost-savings	
	Optimisation processes – Smarter decision support	
	Optimisation processes – Smarter decision support – Outcome-focused by driving actual intervention, not simple alerts	
	Optimisation processes – Stabilising the implemented EHR	
	Optimisation processes – Thoughtful change management	
	Optimisation processes – Upgrade and implementing/building new features/modules	
	Optimisation processes – Using data in EHR	
2) What advancements are hospitals making, post go-live, by leveraging the implemented EHR?	Results of optimisation – Capturing more core measure reporting	
	Results of optimisation – Improved clinical outcome	
	Results of optimisation – Improved collaboration	
	Results of optimisation – Improved compliance to best practice	
	Results of optimisation – Improved documentation/charting	
	Results of optimisation – Improved efficiency	
	Results of optimisation – Improved EHR system	
	Results of optimisation – Improved practice/process/workflow	
	Results of optimisation – Improved quality of care	
	Results of optimisation – Improved safety	
	Results of optimisation – Improved usability	
	Results of optimisation – Increased end user/physician satisfaction	
	Results of optimisation – Increased patient satisfaction	
	Results of optimisation – Less training required	
	Results of optimisation – Little improvements in clinical care	
	Results of optimisation – Reduced burden of documentation of clinicians	
	Results of optimisation – Reduced time spent with EHR	
	Results of optimisation – ROI, value, cost savings	
3) Are there any pattern(s) of optimisation processes in hospitals and, if so, what are they specifically?	Principles governing optimisation prioritisation – Efficiency/Usability	Not limited to these codes only
	Principles governing optimisation prioritisation – Process Improvement	
	Principles governing optimisation prioritisation – Quality	
	Principles governing optimisation prioritisation – Regulatory requirements	
	Principles governing optimisation prioritisation – ROI	
	Principles governing optimisation prioritisation – Safety	
	Misc. – Converging of clinical, administrative, and financial data	
	Perspective – Not IT project but organisational project	
	Perspective – Outcome oriented, beyond successful implementation	
4) What are barriers and facilitators to optimisation?	Barriers – Bureaucratic process and/or multiple layers of approval	
	Barriers – Complexity of EHR	
	Barriers – Difficulty in engaging end users	
	Barriers – Lack of coordination between requests	
	Barriers – Lack of standardised practice/process/policies	
	Barriers – Limited resources	

	Barriers – Misunderstanding optimisation as IT project	
	Barriers – People, resistance to change	
	Barriers – Poor communication/channel to connect IS	
	Barriers – Reaching consensus among stakeholders	
	Barriers – Technically not possible to make it happen	
	Barriers – Time	
	Facilitators – Advisory/executive committees/councils/groups	
	Facilitators – Connection with users & business owners face-to-face/indirectly	
	Facilitators – Culture of organisation driving improvement	
	Facilitators – Dedicated resources/Commitment	
	Facilitators – Demonstrating value in optimisation	
	Facilitators – Engaging operation/leadership	
	Facilitators – Engaging super users, end users, physicians	
	Facilitators – Good timeline to train users, not rushing	
	Facilitators – Identifying champions	
	Facilitators – Informatics people	
	Facilitators – Organisational change (*e.g.* leadership change)	
	Facilitators – Process improvement engineer	
	Facilitators – Regular meetings	
	Facilitators – Regulatory changes	
	Facilitators – ROI	
	Facilitators – Setting specific vision aligned with the organisation's goals/strategies	
	Facilitators – Supportive leadership	
	Facilitators – Usability test	
	Facilitators – User training/learning/education	
	Facilitators – User's needs	
	Advice – Important to plan and execute optimisation	
	Advice – Keep learning and open to changes	
	Advice – Learning/networking other organisations who have done	
	Advice – Partnership with vendors	
	Advice – Putting dedicated resources for optimisation	
	Advice – Support clinical workflow, not dictate	
5) Overall understanding of EHR optimisation including its definition	Define Optimisation – Continually fine-tuning and improving your product to make it more usable and more efficient for end users	Not limited to these codes only
	Define Optimisation – Continued process by nature, always working progress	
	Define Optimisation – Finding a balance within limited resource while not overwhelming the clinician with change	
	Define Optimisation – Having a seamless health information records	
	Define Optimisation – Improving efficiency of clinician's practice	
	Define Optimisation – Increasing efficiency	
	Define Optimisation – Increasing end-user satisfaction	
	Define Optimisation – Usability, more usable for end users	