

**AUSTRALIAN COMMISSION  
ON SAFETY AND QUALITY IN HEALTH CARE**

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# **Impact of Digital Health on the Safety and Quality of Health Care**

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## Preface

This preface was written by the Australian Commission on Safety and Quality in Health Care (the Commission) to provide context and background to the report which follows, *Impact of Digital Health on the Safety and Quality of Health Care*. The main report was written by the Research in Implementation Science and eHealth, University of Sydney on behalf of the Commission.

## Background

The role of the Commission is to lead and coordinate national improvements in the safety and quality of health care. The Commission works in partnership with the Australian Government, state and territory governments and the private sector to achieve a safe, high-quality and sustainable health system. In doing so, the Commission also works closely with patients, carers, clinicians, managers, policymakers and healthcare organisations.

Key functions of the Commission include developing national safety and quality standards, developing clinical care standards to improve the implementation of evidence-based health care, coordinating work in specific areas to improve outcomes for patients, and providing information, publications and resources about safety and quality.

The Commission works in four priority areas:

1. Patient safety
2. Partnering with patients, consumers and communities
3. Quality, cost and value
4. Supporting health professionals to provide safe and high-quality health care.

The Commission's combined work plan 2017–2020 specifies development of a report on the impact of health IT on the quality of patient care.

Digital initiatives in health can produce significant benefit for patients and healthcare providers. Benefits can include:

- Improved outcomes
- Reduction in unwarranted variation
- Reduction in preventable harm
- Improved appropriateness of health care
- Improved patient centeredness
- Increased opportunities for monitoring and quality improvement.

The report will assist governments and healthcare organisations to identify elements of digitisation in health care that best improve the safety and quality of patient care. It will also help healthcare organisations to monitor their digital progress against best-practice targets, and to increase the value they derive from their digital activities.

## Key findings

The review findings are focused on five digital health interventions:

- Electronic patient portals
- Electronic patient reminders (mobile technologies)
- Information-sharing at discharge (electronic discharge summary or EDS)
- Computerised provider order entry (CPOE) including electronic prescribing
- Clinical decision-support systems (CDSSs).

### Electronic patient portals

Electronic patient portals provide patients with secure access to their health information. They help consumers to become active participants in decision-making about their health care.

Findings of the report include:

- Successful patient portals include functions such as secure messaging, patient reminders, and prescription refill orders
- Electronic patient portals are most successful when integrated with other interventions that support patients to act on the information available in the portal, such as reminders and clinical decision support tools
- There are consistent disparities in electronic portal use across patient populations, reflecting the 'digital divide' between patients from different socioeconomic backgrounds
- Health professional engagement in and support for electronic patient portal use may increase adoption and use by patients
- Making electronic patient portals available within clinical contexts enables greater access and provides opportunities for health professionals to demonstrate application of portal functions in support of treatment plans.

### Electronic patient reminders (mobile technologies)

Men, and people under 40 years of age and from low socioeconomic backgrounds, are at higher risk of non-attendance at scheduled appointments and poor compliance with medication regimens.

Findings of the report include:

- The use of mobile technologies may be effective in delivering reminders to a large proportion of the patient population group; however, the appropriateness of mobile technologies is unknown for some groups, such as older patients and patients who do not speak or read English
- Appropriate timing and delivery of reminders may avoid reminder fatigue and support successful adoption of patient messaging interventions

- Bidirectional messaging may promote successful outcomes by generating personalised communication between healthcare professionals and patients; however, this may also impact on clinical workflow.

## Information-sharing at discharge (electronic discharge summary)

Timely sharing of high-quality information at transitions in care, such as discharge from hospital, is critical to continuity of care and promotion of patient safety.

Findings of the report include:

- Electronic discharge summaries (EDSs) may promote timeliness of preparation and transmission of patient information to primary care providers
- EDSs may be more successful when auto-populated and auto-sent with information from a hospital's EMR, when delivered via secure email, and when integrated with reminders to health professionals to complete the EDS
- Health professionals appear to need training and support to facilitate successful generation and use of the EDS.

## Computerised provider order entry

Findings of the report include:

- Computerised provider order entry (CPOE), including electronic prescribing, appears to be most successful when implemented in conjunction with additional software components, particularly CDSSs
- Combining CPOE with targeted education modules and performance feedback may further enhance CPOE utilisation and adherence to medication guidelines
- Interoperability of CPOE with existing electronic systems appears to improve the success of CPOE adoption and usability
- Tailoring CPOE systems to the local healthcare setting increases its appropriateness.

The literature showed electronic prescribing has produced improvements in organisational efficiency and the safety of prescribing.<sup>1</sup>

## Clinical decision-support systems

Clinical decision-support systems (CDSSs) match patient-specific characteristics to a database, and create personalised predictions for assessing disease status, diagnosis, appropriate treatment options and other clinical decisions. CDSSs can also generate patient-specific reminders or alerts, when deviation from recommended care is detected.

Findings of the report include:

- CDSSs appears to be most successful when implemented in combination with additional software components

- Interoperability of CDSSs with existing electronic systems may improve the success of its adoption and usability
- CDSSs that targets decision support according to a local minimum set of indicators appear to have greater uptake and impact on quality of care.

The literature has shown CDSSs have had a positive impact on patient safety – for example, in the areas of accessibility, clinical judgement, data integrative, guidelines adherence, indicated care, organisational efficiency, patient outcomes, resource utilisation and safety prescribing.<sup>1</sup>

## Conclusion

Introducing digital health initiatives into healthcare organisations can produce significant benefits to patients and healthcare providers. Improvements to quality, safety and efficiency of patient care are achievable via digital interventions. The literature indicates that a combination of digital interventions may yield greater benefit. However, the successes of these interventions are dependent on ensuring a rigorous implementation process.

There is limited published evidence regarding approaches to measuring digital health. The variation among implemented digital health interventions limits comparative data and knowledge-sharing. Measurements are typically focused on structural, process, or outcome metrics. There are exemplar measurement frameworks available. Customisation of such frameworks, however, will elicit specific data related to the intervention, which will enable greater attribution.

## Next steps

The Commission will continue to work with states and territories, the Australian Digital Health Agency, and other healthcare providers to identify best-value approaches to health IT initiatives which optimise patient safety and the quality of care.

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<sup>1</sup> Eden R, Burton-Jones A, Scott I, Staib A, Sullivan C. The impacts of eHealth upon hospital practice: synthesis of the current literature. Deeble Institute evidence brief. 2017;16. Epub 2017/10/17

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# Acronyms and abbreviations

ADE adverse drug event

CDSS clinical decision support system

CPOE computerised provider order entry

ED emergency department

EDS electronic discharge summary

EHR electronic healthcare record

HIT health information technology

ICT information and communications technology

ICU intensive care unit

IT information technology

UK United Kingdom

US United States

# 1. Summary

The University of Sydney was contracted to develop a report on the effects of five digital health interventions on patient safety and quality of care:

- Electronic patient portals
- Electronic patient reminders (mobile technologies)
- Information-sharing on discharge (electronic discharge summary)
- Computerised provider order entry
- Clinical decision support systems.

The report used two approaches: 1) a synthesis of systematic reviews; and 2) interviews with informants from Australia, the United States and the United Kingdom.

The report is intended to provide a resource for organisations and individuals to:

- Identify elements of digital health that best improve safety and quality
- Explain existing approaches to self-assess, monitor and benchmark best-practice digital health.

This report includes a review of the literature, main findings, existing approaches to measurement and a glossary of terms.

## 1.1 Changing the health context and its effect on program evaluation

The literature and informant interviews provided insight into:

- The current state and future direction of digital health interventions
- The effect of digital health interventions on patient safety and quality of care
- Priorities for future development of the digital health landscape.

These insights need to be considered in the context of the broader and rapidly evolving information and communication technology (ICT) environment. Substantial investments have been made globally in digital health. However, health lags behind many other industries when it comes to introducing and using cloud-based solutions, machine learning, cognitive computing and mobile technologies.

In addition, globally, health systems are challenged by the interoperability of health ICT infrastructure and their integration across health service organisations. Therefore, there are considerable challenges in the transfer and access of reliable data in real time.

It was apparent that leading health service organisations with innovative digital health systems are employing a combination of technologies within larger integrated solutions. This further complicates the interpretation of, and ability to attribute, success to single digital health intervention types.

## 1.2 Literature and findings

Four main findings can be drawn from this study:

- The evidence suggests that the five digital health interventions reviewed in this report can improve quality of care, patient safety and patient outcomes
- The most convincing evidence relates to established systems such as computerised provider order entry systems; there is less evidence surrounding newer systems such as patient portals
- There is evidence that the featured digital interventions could negatively affect practice, user experience and outcomes if not designed or implemented appropriately
- It is clear from the literature and informant interviews that the manner in which systems are developed and implemented determines any negative or positive effects of digital health interventions on patient safety and quality of care.

The findings and critical success factors for the five digital health interventions are summarised in Table 1.

**Table 1: Summary of the main findings and critical success factors**

Digital health intervention	Main findings and critical success factors
Information-sharing on discharge	<ul style="list-style-type: none"> <li>• Electronic discharge summaries (EDSs) may promote faster preparation and transmission of patient information to primary care clinicians</li> <li>• EDSs may be more successful when auto-populated with information from a hospital's electronic health record (EHR), when delivered through secure email, and when integrated with reminders to clinicians to complete the EDS</li> <li>• Clinicians appear to need training and support so they can successfully use EDSs</li> </ul>
Electronic patient portals	<ul style="list-style-type: none"> <li>• Successful patient portals appear to include functions such as secure messaging, reminders and prescription refill orders</li> <li>• Electronic patient portals appear to be most successful when integrated with other interventions that support consumers to act on the information available in the portal, such as reminders and clinical decision-support tools</li> <li>• There are consistent disparities in electronic portal use across consumer populations, reflecting the 'digital divide' between consumers from different socioeconomic backgrounds</li> </ul>
Patient reminders using mobile technologies	<ul style="list-style-type: none"> <li>• The use of mobile technologies may be effective in delivering reminders to a large proportion of consumers; however, the appropriateness of mobile technologies is unknown for some groups, such as older consumers, and culturally and linguistically diverse consumers</li> <li>• Appropriate timing and delivery of reminders may avoid reminder fatigue and support successful adoption of patient messaging interventions</li> <li>• Two-way messaging may promote successful outcomes by generating personalised communication between clinicians and consumers; however, this may also affect clinical workflow</li> </ul>

Digital health intervention	Main findings and critical success factors
Computerised provider order entry (CPOE)	<ul style="list-style-type: none"> <li>• CPOE appears to be most successful when implemented with extra software components, especially CDSSs</li> <li>• Interoperability of CPOE with existing electronic systems appears to improve the success of CPOE adoption and usability</li> <li>• Tailoring a CPOE system to the health service organisation increases its appropriateness</li> </ul>
Clinical decision-support systems (CDSSs)	<ul style="list-style-type: none"> <li>• CDSSs appear to be most successful when implemented in combination with extra software components</li> <li>• Interoperability of a CDSS with existing electronic systems may improve the success of its adoption and usability</li> <li>• CDSSs that target decision support according to a local minimum set of indicators appear to have better uptake and effect on quality of care.</li> </ul>

The literature review showed mixed results about the effect of electronic patient portals on encouraging consumers to engage with clinicians.<sup>1</sup> Similarly, mobile text message reminders have scant evidence regarding patient compliance with medication regimens.<sup>2</sup> A combination of digital health interventions, such as CPOE and CDSSs, have shown more positive effects on patient safety compared with standalone interventions.<sup>3-6</sup>

The successful implementation of the digital health interventions is linked to thorough consultation among many different clinicians. The alignment of digital interventions with workflow is attributed to user acceptance, adoption and positive outcomes.<sup>7-12</sup> Digital interventions have also demonstrated a positive effect on clinician–consumer communication.<sup>3,13,14</sup> Electronic patient portals have demonstrated an improvement in consumer satisfaction due to the convenience of prescription refill ordering, sharing personal health information and having easy access to information.<sup>15</sup>

As digital health technologies are evolving rapidly, there is much to be learned about how digital health interventions should be most effectively designed, implemented and used. Future research should consider:

- Standardisation of digital health measurement strategies, to enable meaningful comparisons between different digital health interventions
- Definitions and measurement of main outcomes, including patient health outcomes
- Benefits realisation through rich case studies; these which best provide the information needed by implementers to support decision-making about digital health interventions
- Capitalising on existing, unpublished data on digital health evaluations by supporting organisations to share their findings, thus driving innovation and progress in digital health implementation.

## 2. Introduction

Information and communication technology (ICT) is a broad term that covers any product or program that stores, retrieves, manipulates, transmits or receives digital information. The application of ICT in health care is known as health information technology (HIT). HIT refers to different products, technologies and services that help users to collect, share and use health information for different purposes. The implementation of HIT will be referred to as digital health interventions throughout this report for clarity and consistency.

### 2.1 Context and background

The Australian Commission on Safety and Quality in Health Care (the Commission) promotes and supports the safe and effective implementation of HIT in Australia. Using HIT can improve the quality, safety and efficiency of health care. However, the practical implementation of HIT in a complex and dynamic healthcare environment can be challenging. The Commission has produced different resources to help health service organisations and clinicians with best-practice implementation.

This project aims to identify elements of digitisation in health care that best improve the safety and quality of patient care, to drive safe and effective use of national digital health infrastructure into the future. This includes identifying existing approaches to self-assess, monitor and benchmark uptake of recommended digital health interventions. The Commission's rolling three-year work plan features this project under deliverables for 2017–18.

### 2.2 Aims and scope

The Research in Implementation Science and eHealth group, the University of Sydney, was engaged by the Commission to:

- Conduct a literature review and analysis of any grey literature about digital health interventions that have improved patient safety and quality of care, and identified approaches to benchmark uptake of digital health
- Conduct five informant interviews to document experiences of digital transformation not captured in published literature
- Consolidate (and develop, if appropriate) definitions to support the understanding of digital health terminology at the Commission.

The report synthesises this information and outlines several findings.

## 3. Method

The project method was underpinned by the importance of a rigorous evidence base, and a consultative approach consisting of a literature review and informant interviews.

### 3.1 Definition of review scope

The five digital health interventions that are explored in this report, and were nominated by the Australian Commission on Safety and Quality in Health Care, are:

- Electronic patient portals
- Electronic patient reminders (mobile technologies)
- Information sharing on discharge (electronic discharge summaries)
- Computerised provider order entry
- Clinical decision-support systems.

Computerised provider order entry (CPOE) is the most commonly used term in the literature to represent electronic order entry. In some Australian states and territories, 'electronic medication management' and 'order entry' are the preferred terms. CPOE replaces traditional paper tools and requires clinicians to directly place orders for medicines, tests or studies into an electronic system, which transmits the order directly to the recipient responsible for implementing the order.<sup>16</sup>

Digital healthcare terms, relevant to the search strategy, were considered and compiled as a glossary in this report (Appendix A).

### 3.2 Literature review

Based on the five focus areas in Section 3.1, a scoping review was conducted to address the following research questions:

- What is the impact of <insert digital health type> on the safety and quality of health care?
- What factors contribute to successful <digital health type> implementation?

Search methods included:

- Systematic database searches
- Hand searches of target journals
- Snowballing and citation tracking
- Targeted review of websites of key organisations associated with safety and quality in health care
- Web searches for relevant grey literature.

The search incorporated results of systematic reviews published in a five-year period, from 2012 to 2017.

Publications dated pre-2012 were included only if considered to be seminal work or of significant impact. The search strategy was developed in collaboration with an academic librarian from the Faculty of Health Sciences, University of Sydney (Appendix B).

### **3.3 Informant interviews**

Interviews with key informants served as the 'lived experiences' of organisations and individuals actively engaged in the development, implementation and review of digital health interventions. The informant interviews captured experiential evidence not published or reported in the literature. In particular, informant interviews were used to gather information about the practicalities of digital health elements that contribute to positive safety and quality outcomes. This was considered an important project component, given the practical nature of the project outputs.

Each interview was guided by a pre-approved interview script (Appendix C) and approved by the University of Sydney Ethics Committee. Interviews were transcribed verbatim, and two reviewers thematically analysed them for emerging and final themes. During the analysis, case study examples and illustrative quotes were highlighted and grouped by themes. These examples and quotes are presented throughout this report to complement the main findings from the literature review.

## 4. Findings

This chapter describes the main findings from the literature review and the informant interviews.

### 4.1 Literature review findings

The literature searches retrieved more than 500 results. After removing duplicate reports and reviewing the abstracts, 84 systematic reviews were selected for full text review. Most of the publications were from the United States (US), Canada, the United Kingdom (UK), Australia and Europe. Results were largely associated with hospital-related and primary care digital health interventions. Systematic reviews on various clinical topics were noted in the literature, including in the clinical areas of diabetes, cardiology, cancer care and mental health.

Although the digital health literature base is expanding rapidly, there has not been a commensurate increase in the understanding of the effects of digital health, or how digital health can be used to improve health and health care. Most studies were of low to moderate quality due to considerable heterogeneity of technology design, implementations and context. Most results of this review are related to process outcomes, with far fewer results about the clinical outcomes for patient safety and quality. It is acknowledged that it is challenging to attribute patient outcomes to a single digital health intervention. Further details of the literature review results have been analysed and synthesised into relevant sections throughout this report.

Consistent use of standardised terminologies in digital health is often limited due to the complexity and variability of health service organisations. A desktop scan was done to help understand current patterns of terminology use. A glossary of terms was assembled to inform relevant search strategies and to validate the consistent use of digital health terminology (Appendix A).

#### 4.1.1 Electronic patient portals

This literature search identified 10 systematic reviews about how electronic patient portal implementation affects patient safety and quality of health care. Most of the systematic reviews<sup>1,3,13-15,17,18</sup> had all patient subgroups and types of health service organisations in their inclusion criteria. One focused on electronic portals for people with diabetes<sup>19</sup>, and another focused on electronic portals for paediatric patients.<sup>20</sup>

#### 4.1.2 Patient reminders using mobile technologies

The literature search identified 21 systematic reviews about the effects of patient reminders using mobile technologies.<sup>2,4,21-39</sup> These reviews looked at different safety and quality outcomes, including:

- Medication adherence
- Appointment attendance

- Preventive health care and screening
- Self-management of long-term illnesses
- Treatment compliance in mental health.

### 4.1.3 Information sharing on discharge

This literature search identified three systematic reviews about the effects of electronic discharge summaries (EDSs) on safety, and that were transmitted from a hospital to primary care providers.<sup>40-42</sup> None of the systematic reviews focused solely on EDSs; rather, the authors investigated different interventions to improve patient discharge. Findings were supplemented by reviewing the studies included in each systematic review and published after the year 2000. Thus, a total of nine studies were reviewed<sup>43-51</sup>, which explored different EDS systems and processes. Although these studies were all published within the past

11 years, the EDS systems evaluated included some that relied on outdated technologies. For instance, in most of the studies, EDSs were generated using electronic templates, then transmitted to primary care providers using conventional mail<sup>45,50,51</sup>, or electronic or conventional fax.<sup>46,48</sup> In contrast, email<sup>43</sup> or secure messaging<sup>44</sup> was used to transmit EDSs in only two of the included studies.

### 4.1.4 Computerised provider order entry

The literature search identified 21 systematic reviews about how computerised provider order entry (CPOE) affects the safety and quality of health care. Most of the systematic reviews looked at the hospital setting, and included:

- All patient subgroups for inpatients and outpatients<sup>16,52-57</sup>
- Intensive care units (ICUs)<sup>5,58,59</sup>
- Emergency departments (EDs)<sup>6,60</sup>
- Acute care<sup>61</sup>
- Transplant centres.<sup>62</sup>

One systematic review looked at primary care<sup>63</sup> and the remainder did not specify a setting or patient subgroup.<sup>13,64-68</sup> Seven of the systematic reviews focused on CPOE, whereas the rest focused on investigating different digital health interventions to improve patient safety and quality, which included CPOE. CPOE was often studied in combination with clinician decision-support systems (CDSSs). Overall, assessment of CPOE mostly used process measures rather than clinical outcome measures.<sup>6,54</sup>

### 4.1.5 Clinical decision-support systems

The literature search identified 29 systematic reviews about how CDSSs affect the safety and quality of health care. Eight systematic reviews focused on primary care<sup>8,9,69-74</sup>, two on EDs<sup>60,75</sup>, two on diabetes care<sup>10,76</sup> and two on acute kidney injury.<sup>77,78</sup> Beyond these studies, other patient groups and healthcare settings included ICUs<sup>79</sup>, transfusion practice<sup>11</sup>, mental

health<sup>80</sup>, paediatrics<sup>81</sup>, acute care<sup>82</sup>, cardiovascular management<sup>83</sup>, HIV care<sup>84</sup> and ancillary departments.<sup>85</sup> The remaining studies did not specify a setting.<sup>12,86,87</sup> Most systematic reviews focused on the implementation of CDSS as a standalone product, whereas the remainder focused on investigating different interventions to improve patient safety and quality, which included CDSSs. As with CPOE, CDSS research studies process measures rather than clinical outcome measures.<sup>83</sup>

#### 4.1.6 Grey literature

A number of highly informative and actionable resources were identified in the grey literature review, including detailed reports from key international organisations for safety and quality. The National Health Service in the UK provides a guide to digital health assessment and mapping of digital roadmaps.<sup>88,89</sup> Similarly, the National Quality Forum in the US provides a HIT Measurement Framework.<sup>90</sup> The World Health Organization has a sociotechnical model for measuring digital health interventions at multiple points throughout the digital intervention life cycle.<sup>91</sup> The US-based Agency for Healthcare Research and Quality's Health Information Technology unit describe national digital health implementation in the guide *Health IT-Enabled Quality Measurement: Perspectives, pathways, and practical guidance*.<sup>92</sup> Recently, Standards Australia produced the *Digital Hospital Handbook*, which informs the design and implementation of digital hospitals.<sup>93</sup>

## 4.2 Informant interview findings

Interviews with five key informants were conducted. Key informants are considered to be international leaders in digital health, and are based in different healthcare, academic, government and peak body organisations in Australia, the US and the UK. These key informants have broad experience in the design, implementation and evaluation of digital health interventions at local, regional or national levels. Specifically, key informants drew on their direct experience with electronic health records, CPOE or electronic medication management, CDSSs, digital informatics, and electronic patient portals. Key informants also included individuals who have held roles in national peak bodies, governmental statutory authorities and national agencies supporting digital health systems and strategies, standards development, and benchmarking.

To protect individual identities, specific details on employer organisations have not been included, nor has any information of a sensitive nature described by key informants.

However, due to the nature of this study, it is possible that individual key informants may be identifiable from the information provided in this report. A statement that acknowledges this was provided in the Participant Information Sheet.

### 4.2.1 Electronic patient portals

The increasing use of electronic patient portals in health reflects a growing movement towards person-centred care. Electronic patient portals help consumers to become active participants in decision-making about their health care.<sup>90</sup> Health service organisations are increasingly being required to provide person-centred care, and support consumers to share in decision-making and become active participants in their own care.<sup>94</sup>

### Drivers of uptake: increasing patient engagement

*The main driving force behind our implementation of patient portals was regulation: The Affordable Care Act, Obamacare. We had to communicate with our patients ... It was part of this whole philosophy of patient and family engagement.*

Electronic patient portals have been defined by the United States Government as ‘a secure online website that gives patients convenient 24-hour access to personal health information from anywhere with an internet connection’.<sup>95</sup> More often, patient portals are tethered to health service organisations’ EHRs. Alternatively, electronic patient portals may stand alone, as is the case with Australia’s My Health Record system, a personally controlled healthcare record. One key informant described the advantage of personally controlled healthcare records in terms of empowering consumers to be involved in their own health care.

### Personally controlled health information

*I think the key thing is that the fact that it provides people with access to, and control of, their own personal health information like they've never had before ... It will be like the way we can't imagine what we did before we had a mobile phone 25, 35 years ago. It will be a bit of a game changer because the way people have their own knowledge of what's happened in their health care will be so greatly enhanced. They'll be able to engage, and be much better activated in terms of their connections to their treatment plans and their own decision-making abilities as well. Having access to their own personal health information will actually transform the way people interact with their healthcare providers.*

Electronic patient portals may encompass different functions, including the ability for consumers to:

- View and download discharge summaries and personal health information
- Schedule appointments
- Exchange secure messages with clinicians
- Request prescription refills.

In certain contexts, access to an electronic patient portal is combined with other services, such as case management and telehealth, as part of a larger patient management system.

Electronic patient portals seem to have the potential to enable the convergence of technologies into sophisticated, integrated solutions. Key informants highlighted this as an element that may support positive safety and quality outcomes in the future.

### The My Health Record system: a basis for converging technologies

*[The] My Health Record [system] is going to be the basis, we envisage, that a lot of third-party applications will sit on top of, and draw information from. The long-term vision is that you won't be looking at this through our consumer portal or our provider portal at all. It is a series of pipes where all of the information will flow to a central point, and then third-party applications and vendor software systems can sit on top of the system and pull out the relevant stuff, and present it to people in a way that's digestible and easy to use, and looks like your iPhone stuff that you're used to.*

The literature has identified four ways that electronic patient portals may support improved outcomes<sup>14</sup>:

- Providing consumers with secure access to their personal health information engages them in decision-making and motivates them to follow treatment regimes, resulting in

improved health outcomes

- Patient portal functions, such as reminders and decision support tools, may empower consumers to act on the information presented, thus improving adherence to treatment plans
- Patient portals enable communication between consumers and clinicians, enabling development of strong clinician–consumer relationships, translating into improved continuity of care, consumer satisfaction and clinical outcomes
- Electronic portals may provide consumers with convenient access to the services, resources and information they require, resulting in improved consumer satisfaction.<sup>14</sup>

The evidence is currently insufficient to identify any effects of electronic portals on patient outcomes. Some studies suggested that electronic portal use may lead to improved patient safety and quality of care. However, these effects were neither consistent nor strong across all studies.<sup>13,20</sup> For instance, in Kruse et al.'s review<sup>13</sup>, only 10 out of the 27 included articles reported positive patient outcomes associated with portal use. Conversely, negative outcomes are rarely reported.<sup>13,14</sup> Nevertheless, there are examples of individual studies in which patient portal use was associated with positive outcomes across different chronic diseases, such as diabetes, hypertension and depression.<sup>1,13,15,20</sup> Improved medication adherence<sup>1,13,14,17</sup> and increased use of preventive medicine and screening<sup>1,13</sup> have also been associated with portal use. However, these positive findings were not uniform and were not supported across a wider body of literature.

Similarly, it was suggested that electronic portal use may help to support consumer engagement, consumer empowerment in decision-making<sup>13,15,17</sup> and improved self-management.<sup>13</sup> However, conflicting results are reported across the literature. The available evidence is limited due to weak study designs and small numbers of studies reporting data for these outcomes. Ammenwerth et al.<sup>17</sup> concluded that 'better-informed patients are not necessarily healthier patients' (p. 10). This may be because providing health information via an electronic portal is only one of many factors that support quality health care. Pairing electronic patient portals with other health services, such as case management<sup>15</sup>, or with other digital health interventions, such as patient reminders, decision support tools and secure messaging<sup>17</sup>, was found to be more effective. A combined approach better supported and guided patients to use the information in electronic portals.<sup>17</sup>

Consumer satisfaction with electronic portals is generally high, especially when portals feature secure messaging functions that enable communication with clinicians.<sup>13,14</sup> Overall, consumers found information in portals useful and valuable<sup>15</sup>, felt it improved communication with their clinicians<sup>13</sup> and increased their prominence in person-centred care.<sup>1,13</sup> Consumers also favoured portal functions that offer convenience, such as prescription refill ordering, access to medical records and the ability to share these records with others.<sup>3</sup> Clinicians appear to have more negative attitudes about electronic portals than their patients. Clinicians are reported to be concerned about consumers' reactions to reading their clinical notes; liability, potential privacy and security issues<sup>3,15</sup>; the accuracy of consumer-entered data; and the effect on the clinician–consumer relationship.<sup>3</sup> However, these concerns appear to resolve over time and with more experience in using the portals.<sup>96</sup>

Key informant comments reflected the published evidence about the effects of portal use on consumer satisfaction and clinical outcomes. Although the key informants were unsure about associated health outcomes, one key informant reported high electronic patient portal registration rates and an upwards trend in portal visits in their cancer centre, indicating high consumer satisfaction. This key informant believed that the main outcome of interest targeted by portals was that of consumer engagement.

#### Electronic portals and patient engagement

*It's more about the quality and the engagement with the care team, emailing and getting medication lists from primary care. We can add something.*

It has been hypothesised that electronic patient portals may support improved quality of care by reducing unnecessary healthcare use and allowing clinicians to focus on patients with higher needs. There are mixed results in the literature for the effect of electronic patient portal use on healthcare use. Some studies have demonstrated an association between electronic portal use and lower rates of in-person specialist visits, visits to the emergency department and telephone conversations with clinicians.<sup>3,13-15,17,20</sup> These resource savings are not consistent across the studies. In contrast, some studies have found portals to be associated with increased consumer communication with clinicians, via secure messaging, telephone contact and requests for extended consultations.<sup>13</sup> In some studies, electronic patient portal use has been associated with improvements in continuity of health care<sup>13</sup>, such as decreased non-attendance<sup>3,13</sup> and, when paired with patient appointment reminders, increased attendance at clinic appointments.<sup>3</sup> However, these observations are not consistent. Overall, it is unlikely that electronic patient portals will have substantial effects on health care use.<sup>15</sup> Electronic patient portals appear to complement, rather than substitute for, existing health services.<sup>14</sup>

Electronic patient portal research has focused on exploring the differences in portal use across consumer populations. Promotion and use of electronic patient portals by clinicians appear to have a strong influence on patients' own sustained use of electronic portals.<sup>3,19</sup> In addition, consumers' interest in, and ability to use, portals are heavily influenced by personal factors, with socioeconomic disparities in portal use consistently identified.<sup>14</sup> Consumers from culturally and linguistically diverse backgrounds, and those with lower education and income levels tend to use portals less often.<sup>3,15,19,20</sup> In contrast, patients (and their carers) with chronic health conditions and patients with comorbidities tend to use portals more.<sup>3,19,20</sup> Younger, well-educated consumers and those with higher computer literacy are also more positive about using electronic portals.<sup>1,3,13,15,19</sup> The apparent 'digital divide' between socioeconomic groups – in terms of having access to the internet and home computers – may further prevent disadvantaged groups from having equal access to portals.<sup>1,19</sup>

Similar observations about the influence of personal factors, such as the impact of chronic disease and age on portal use, were voiced by one key informant.

### Disparities in patient portal use

*We know we've got a very high registration rate. Maybe it's the oncology patients that want to be informed. They're hungry for knowledge. They're even encouraged to register before their first visit and complete a very extensive, online personal health assessment before the first visit.*

*I'm challenged looking at the age of people walking through our corridors. We're surrounded by many elderly patients. You know, the bulk of our insurance carrier is Medicare, people over 65. I just wonder how much they would use it.*

Further, health literacy and numeracy appear to exert a strong influence on consumers' use of electronic patient portals.<sup>3,13,20</sup> When using an electronic portal, consumers are supported in accurately entering their data, understanding medical terminology, interpreting test results and acting on information. Such disparities in health literacy and numeracy may partially explain differences in use in different sociodemographic groups. Attention to health literacy and numeracy appears to be an essential element of portal design, which is necessary to support positive patient outcomes. Otherwise, consumers may be unable to use portals to their full extent without the help of clinicians, and consumers are at risk of entering incorrect data or misinterpreting the available information.<sup>13</sup>

#### Main findings and critical success factors:

- Successful patient portals appear to include functions such as secure messaging, patient reminders and prescription refill orders
- Electronic patient portals appear to be most successful when integrated with other interventions that support patients to act on the information available in the portal, such as reminders and clinical decision support tools
- Electronic portal use is consistently different across consumer populations, reflecting the digital divide between consumer from different socioeconomic backgrounds
- If clinicians are engaged in, and support, electronic patient portals, then consumers may use these portals as well
- Making electronic patient portals available within the clinical context allows clinicians to have better access to them, and provides more opportunities for clinicians to use these portals when designing treatment plans.

### 4.2.2 Patient reminders using mobile technologies

Non-attendance at scheduled appointments is a barrier to patients receiving timely evidence-based health care. It is also a major source of lost resources and underuse of clinician time.<sup>26</sup> Consumers especially at risk of non-attendance include those that are men, aged under 40 years and from low socioeconomic backgrounds.<sup>36</sup> Similarly, medication non-adherence is a well-documented healthcare issue strongly associated with poor patient outcomes and increased costs to the healthcare system.<sup>32</sup> It has been hypothesised that patient reminders may improve attendance, reduce delays in diagnosis and treatment, and ultimately improve patient outcomes.<sup>26</sup> Given the widespread use and acceptance of mobile technologies across different socioeconomic and cultural groups<sup>29</sup>, such technologies may also potentially support consumer behaviour change. Examples include increasing patient adherence to medication regimes by reminding them of when to take medicines, and through provision of educational and motivational health information. Mobile text messaging interventions have

typically included one-way messages, from clinicians to consumers. Others are two way, allowing consumers to confirm receipt of the message, or indicate whether they have taken their medicine or are able to attend their upcoming appointment.

The literature generally concludes that electronic reminders via mobile text messages are simple and potentially effective ways of supporting medication adherence across different chronic disease conditions<sup>29,35,37</sup>, including asthma<sup>37,38</sup>, diabetes<sup>27,28</sup>, HIV<sup>2,25</sup>, infant and maternal health<sup>33</sup>, and cancer.<sup>22</sup> However, not all systematic reviews demonstrated a consistently positive impact. De Jongh et al.<sup>23</sup> found mixed results for the impact of text messages on patient self-management of chronic conditions such as asthma, hypertension and diabetes. Zapata et al.<sup>4</sup> and Smith et al.<sup>34</sup> found inconsistent findings for oral contraceptive use. Kauppi et al.<sup>30</sup> concluded that evidence for medication adherence in people with mental illness was inconclusive. Similarly, electronic patient reminders were associated with improvements in medication adherence in only three of nine studies included in the review conducted by Mistry et al.<sup>31</sup> The magnitude of positive benefit, although statistically significant, appears to be small and may not necessarily result in improvements in medication adherence.<sup>37</sup>

Overall, the evidence showing that mobile text messages improve medication adherence is promising, but weak.<sup>32</sup> Further, few studies have documented a positive effect of patient reminders for medication adherence on clinical outcomes or quality of life.<sup>23,38</sup> Finitsis et al.<sup>25</sup> found that people with HIV who received text messages to support medication adherence demonstrated improved biological outcomes, such as decreased viral load and increased CD4+ count.

Certain features of patient reminders appear to affect medication adherence differently. For example, Wald et al.<sup>39</sup> found that one-way text messaging interventions had little positive effect on medication adherence. This was compared with two-way text messaging, which was associated with significant improvements. Patients were 20% more likely to adhere to medication regimes when two-way messaging systems were used. Similarly, Finitsis et al.<sup>25</sup> reported that two-way messaging systems produced significantly greater effects on medication adherence than one-way messaging systems. One-way messaging platforms can only support adherence in patients who unintentionally forget to take their medicine.<sup>37</sup> However, two-way messaging may be especially important when supporting adherence in patients who intentionally decide not to take their medicine, for example, due to concerns about risks associated with dosage.<sup>39</sup> Two-way messaging may provide better support than one way, as it may improve consumer engagement, giving clinicians an opportunity to investigate reasons for non-adherence, and to address concerns and provide extra support.

Key informant comments supported the view about the superiority of two-way messaging function of the organisation's patient portal, but also highlighted the subsequent effects on workload.

#### Success in two-way messaging

*Where we've not seen the optimal success from my perspective is the bidirectional exchange of patient information. Within the Cerner's system, there's Message Centre, which is like an inbox and there's a bell-shaped curve of how well that's being used across our organisation. You don't want busy consultants getting a blizzard of emails from patients, but there's a capability to create a pool*

*with the Message Centre, so you can have a nurse do the filter, forward the critical emails to the medical staff to then get a response.*

The design and content of text messages themselves may affect medication adherence. Text messages that are engaging, motivating, non-automated or personalised may be more effective for adherence. Basic, standardised messages with repetitive content may be associated with little or no effect on adherence.<sup>25,31-33,37</sup> Using reminder systems to provide feedback to consumers about their own adherence rates may also increase medication adherence.<sup>97</sup>

As is the case for patient reminders to promote medication adherence, the limited evidence suggests that mobile phone reminders may be effective at improving attendance at scheduled healthcare appointments<sup>21,26,29,33,36</sup>, and in increasing re-attendance and retesting for HIV or sexually transmitted infections.<sup>24</sup> Patient reminders may increase immunisation rates in children and screening rates for different conditions, although the evidence is inconsistent and of low certainty.<sup>33</sup> Studies have found mobile text messages to be more effective than no reminders or postal reminders.<sup>21,26</sup> Mobile phone messaging reminders have also been found to be as effective as<sup>26</sup>, or more effective than<sup>36</sup>, telephone call reminders. Other studies have concluded that there is currently insufficient evidence to support one form of patient reminders over another<sup>24</sup>, including for people with mental illness.<sup>30</sup>

As with medication adherence, there is little published research on whether improved attendance at appointments translates into improved patient health outcomes.<sup>26</sup> Similarly, safety considerations, such as risks to consumers' privacy, have received little attention in the literature. Research into the effect of reminders on health outcomes is critically needed, to understand the degree to which this intervention has affected patient safety and quality.

It is currently unclear what the best timing, rate and degree of personalisation of mobile phone reminders are.<sup>21</sup> Holcomb<sup>28</sup> concluded that weekly text messages best supported positive clinical outcomes for patients with diabetes. Similarly, Finitsis et al.<sup>25</sup> reported that patient reminders delivered less often than daily and that mirrored the individual's medication schedule were more effective at supporting adherence for HIV. More frequent reminders may lead to message fatigue and to patients not responding to reminders. Poorman et al.<sup>33</sup> recommended that, if text messages are used, their content and timing should be varied to minimise reminder fatigue and promote patients' response to alerts. More research about message content, timing and frequency may help to define how text messaging can increase positive outcomes, and inform successful implementation of messaging interventions.<sup>23</sup>

#### **Main findings and critical success factors:**

- Mobile technologies may be effective in delivering reminders to a large proportion of the patient population group; however, the appropriateness of mobile technologies is unknown for some groups, such as older patients and patients who do not speak or read English
- Appropriate timing and delivery of reminders may avoid reminder fatigue and support successful adoption of patient messaging interventions

- Two-way messaging may promote successful outcomes by generating personalised communication between clinicians and consumers; however, this may also affect clinical workflow.

### 4.2.3 Information sharing on discharge

Timely sharing of high-quality information at transitions in care is recognised as critical to continuity of care and promotion of patient safety. An example of a transition of care is between acute and primary care clinicians at patient discharge from hospital. However, in health systems when primary and acute care is provided by separate services, the transmission of discharge summaries is often delayed between both groups of clinicians. Also, the quality of information contained in conventional discharge summaries may be suboptimal. Information about pending test results, discharge planning and medication changes<sup>41</sup> may be left out, which could jeopardise patient safety and quality of care.<sup>40</sup> EDSs aim to consider such challenges by improving processes related to the generation of discharge summaries and their transmission to primary care clinicians. One key informant reinforced the idea that the seamless transfer of information across a fragmented health system is one of the major opportunities for digital health in the Australian context.

#### Digital health as an aid for information transfer

*Digital health is the only way to get safely from one place to another, in terms of information flowing seamlessly from point-to-point within the fragmented health system that we have, in a way that all different providers in the system are looking at the same piece of information at the same time ... The advantage of digital health, particularly from a clinical safety perspective, is the way it can provide clinicians with information immediately when they need to make a decision. So that avoids the delay that can cause errors in clinical care, because we are looking for pieces of information that are missing, or we don't have access to it. We know that many clinicians spend a lot of time looking for information that they never find. That has an impact, obviously, on the way you make a sensible decision.*

EDSs appear to be a promising intervention for promoting patient safety and quality of care; however, high-quality evidence for their use is limited. EDSs can promote timeliness of preparation and transmission of patient information to primary care clinicians.<sup>40-42</sup> Timeliness may be supported by specific automated system features, such as:

- Population of EDSs with information from the hospital's EHR system
- Reminders to complete the EDS
- Electronic delivery of EDSs via secure email or fax
- Electronic notification for primary care clinicians about when EDSs are available on shared EHRs.<sup>41,46</sup>

Findings are mixed about how EDSs affect the quality of information provided, including the completeness and accuracy of the information. Of the five studies included in a review by Kattel et al.<sup>41</sup>, only two found the quality of EDSs to be significantly better to conventional discharge summaries. No evidence in this review suggests that EDSs had a detrimental effect on information quality.<sup>41</sup> However, the review by Unnewehr et al.<sup>42</sup> found a significant reduction in quality of patient information in EDSs in two studies.<sup>49,50</sup> This worsening in quality may be due to time constraints placed on finishing EDSs, word limits in set fields of EDS templates, a lack of training and education on EDSs, and poor integration into routine

workflow. Although legibility appears to be supported by EDSs, Reinke et al.<sup>47</sup> reported that readability may also be compromised when clinicians enter comments directly from progress notes. Thus, unintended consequences of EDS may include the propagation of inaccurate or out-of-context information, potentially having a negative effect on patient safety and quality of care.<sup>90</sup>

The evidence about the effect of EDS on patient outcomes is very limited. Of the included studies, only two investigated adverse outcomes or near misses due to problematic transfer of patient information.<sup>45,46</sup> Both found no statistical difference in these patient outcomes for EDSs compared with conventional discharge summaries. One study in the Kattel et al.<sup>41</sup> review found that consumers viewed the use of EDSs as a sign of improved discharge preparedness.

#### **Main findings and critical success factors:**

- EDSs may help the preparation and transmission of patient information to primary care clinicians on time
- EDSs may be more successful when
  - auto-populated with information from a hospital's EHR
  - delivered via secure email
  - they use reminders to clinicians to complete the EDS
- Clinicians appear to need training and support to enable successful use of the EDS.

#### **4.2.4 Computerised provider order entry**

Medication errors are common and a preventable cause of patient harm.<sup>13,63,69</sup> The ageing population, increasing complexity of medical practice, and patients with multiple comorbidities can all contribute to medication errors.<sup>57,63</sup> Medication errors are reported to occur in up to 11% of all prescriptions and are estimated to cause 2–3% of all hospital admissions in Australia.<sup>85,98</sup> The burden of medication errors and consequent adverse drug events (ADEs) have been shown to have large effects on patient safety and quality of care.<sup>52</sup> Recent research has demonstrated that technology can be used to decrease the incidence of medication errors. CPOE is one of the most widely promoted applications to help clinicians create and manage medical orders.<sup>13,58,63</sup> CPOE replaces traditional paper tools, and can improve communication and provide a robust audit trail.<sup>53,67</sup>

Large-scale investment in, and implementation of, CPOE has been justified on the basis that it can reduce unwarranted variation in the quality of health care.<sup>60,67</sup> However, despite the potential benefits, CPOE systems have not yet been widely adopted by health service organisations in Australia.<sup>13</sup> This may be partially attributed to high initial and ongoing costs, but organisations are also unsure about how much CPOE can contribute to better health care.

The evidence underpinning the effects of CPOE on most safety and quality outcomes remains uncertain.<sup>13,60</sup> CPOE appears to have a limited effect on hospital mortality and length of stay.<sup>60</sup> However, the results of some pre-post design studies, randomised control trials and time series studies suggested that CPOE systems have a positive effect on medication

errors and ADEs. CPOE in hospital settings was associated with reduced numbers of medication errors and ADEs in more than 50% of studies.<sup>64</sup> Also, the automated dose calculation feature of CPOE systems was associated with a 37–80% reduction in medication error.<sup>64</sup>

The implementation of CPOE in hospitals to support the appropriate use of antibiotics has been reported to lead to several benefits, which include:

- Reduced medication errors
- Increased de-escalation (commencement of treatment of a presumed infection with broad-spectrum antibiotics and narrowing drug spectrum based on culture sensitivities)
- Improved sensitivity
- Increased detection of infection
- Improvements in the timely discontinuation of medicines.<sup>54</sup>

CPOE in emergency departments (EDs) has been reported to lead to a 54% decrease in medication errors and ADEs. However, in the review by Keasberry et al., the risk of new medication errors doubled in two out of 16 (12.5%) studies.<sup>60</sup> CPOE systems in paediatric intensive care units (ICUs) have been reported to lead to reduced medication errors, such as prescriptions that are miscalculated, incomplete or illegible, or exceed maximum concentration.<sup>5</sup> Similarly, another systematic review reported an 85% reduction in medication errors in ICUs, which was largely attributed to improved legibility of prescriptions.<sup>58</sup>

Despite some positive reports, most studies reported mixed results and some instances of unintended adverse consequences following CPOE implementation. Adverse consequences include increased medication errors in different health service organisations.<sup>6,53,54,56,57,60,64,65</sup> For example, in a systematic review of CPOE in adult ICU settings, reduced medication errors were demonstrated in three out of five studies, but increased medication errors were reported in the remaining two studies.<sup>59</sup> However, these differences may be attributed to the specifics of a particular intervention, context, consumer demographics and implementation. It may not mean that CPOE is a poor digital health intervention.

Aside from minimising medication errors, CPOE appears to have a positive influence on clinicians' behaviours; they may better adhere to guidelines and use best-practice care. However, as for medication errors, the current evidence for clinicians' behaviour is uncertain and contains mixed results. For example, in the review of hospital CPOE systems by Page et al.<sup>61</sup>:

- 53% of included studies reported a significant beneficial effect on clinicians' behaviour
- 34% reported no significant effect
- 6% reported a significant detrimental effect.

A systematic review on CPOE in EDs reported improvements in clinicians' adherence to guidelines, more appropriate medication orders and increased vaccination rates.<sup>6</sup> Two systematic reviews found that CPOE improved laboratory turnaround times.<sup>60,62</sup> Another review showed<sup>54</sup>:

- Less time to the first dose of antibiotics
- Improved antibiotic selection
- Optimised dosing
- Improved adherence to guidelines
- Fewer antibiotics prescribed overall.

One study found that CPOE improved medication verification times; however, this was not associated with a reduction in time between the medication order and administration.<sup>66</sup>

Although CPOE has reduced medication errors and ADEs in some instances, evidence indicates that CPOE may be more successful when configured with integrated clinical decision support systems (CDSSs).<sup>5,52,54,60,66</sup> This suggests that CPOE functions can be improved when other software components and specialty-specific extensions are integrated.<sup>16,52,99</sup> CPOE configured with CDSS provides clinicians with timely access to patient information and electronic decision support to improve clinical decision-making and the provision of quality clinical care. The combination of CPOE and CDSS is generally associated with a greater reduction in medication errors compared with CPOE systems without extra software components.<sup>5,6,13,52</sup> Manias et al.<sup>5</sup> reported that seven of eight studies included in their review showed significant reductions in medication error rates when CPOE was combined with clinical decision support. In addition, CDSSs incorporated into CPOE were associated with improved guideline compliance regarding medication reconciliation for inpatient providers.<sup>6</sup>

Despite mixed reports on the effectiveness of CPOE, the factors associated with its successful implementation have not been well explored.<sup>13,56</sup> Each CPOE system can vary considerably in terms of functionality, interoperability, cost and involvement of stakeholders in its implementation.<sup>54,63</sup> CPOE implementation is a highly complex sociotechnical intervention, successes and failures may be attributable to intervention design, unique features of the context and specific implementation factors.<sup>56</sup> As a result, unintended adverse consequences reported in the literature may be difficult to anticipate in other contexts.<sup>54</sup> Many of the systematic reviews identified that unintended adverse consequences were due to technical functionality and human factors. For instance, one systematic review identified that sociotechnical factors were not considered during CPOE design, which contributed to new technology-induced errors as a result of computer screen display, dropdown menus, auto-population, wording, default settings and non-intuitive ordering when the system was implemented.<sup>53</sup> This risk highlights the need for tailored CPOE systems appropriate to the health service organisation.<sup>56</sup>

Despite variability in CPOE systems across settings, CPOE alerts are consistently reported to have a potentially detrimental effect on workflow, and constitute a major barrier to successful implementation.<sup>5,16,53,54,57,59,61,63,64,66,67,100,101</sup> Alert fatigue leads to high rates of alert

override, and is a well-recognised result of frequent or irrelevant alerts, and interruptions to workflow.<sup>5,16,59,60</sup> It has been suggested that 49–96% of medication alerts have been overridden as a result of alert fatigue.<sup>60</sup> Alert fatigue has been linked to clinicians overriding critical safety alerts and warnings of serious drug–drug interactions<sup>16,67,90</sup>, which is a major risk to patient safety.

Tailored CPOE alerts have been proposed as a strategy to deal with alert fatigue. For instance, tailored CPOE alerts have been reported to be useful when prescribing unfamiliar medicines or to change the way in which patients are monitored.<sup>64</sup> Some tailored CPOE alerts use historical data to improve the sensitivity and specificity of the alerts, thereby decreasing the frequency of irrelevant alerts. Creation of context-specific alerts using patient-specific information may improve acceptance of CPOE, reduce alert fatigue<sup>61,66</sup> and, as a result, promote patient safety.

#### **Main findings and critical success factors:**

- CPOE appears to be most successful when implemented in conjunction with extra software components, especially CDSSs
- Interoperability of CPOE with existing electronic systems appears to improve the success of CPOE adoption and usability
- Tailoring CPOE systems to the health service organisation increases their appropriateness.

### **4.2.5 Clinical decision support systems**

Numerous clinical guidelines exist, but studies have shown a large discrepancy in the application of best-practice evidence into care, resulting in substantial risks to patient safety.<sup>11,12,80,102-104</sup> Also, there is often a gap in the required clinical training and knowledge for specialised clinical areas and rare disease types.<sup>71</sup> The increasing use of EHR systems offers new opportunities to integrate policy, best-practice guidelines and surveillance.<sup>12,83,103</sup> Current research highlights the potential of CDSSs to help with these challenges encountered in clinical practice.<sup>71,85,102</sup> CDSSs are information technologies that use rule-based algorithms to match patient-specific characteristics to a database.<sup>8,11,71,80,85,105</sup> Case-based reasoning functionality creates personalised predictions for assessing disease status, diagnosis, appropriate treatment options and other clinical decisions.<sup>9,11,83,85,103,105</sup> In addition, CDSSs can generate patient-specific reminders or alerts when deviation from recommended care is detected.<sup>8,10,71</sup> These systems have been widely promoted as a promising approach to improving patient safety and quality, yet adoption rates are relatively low and failure rates of implementation are high.<sup>10,11,72,78,85,102</sup> The literature suggests that the limitations are mostly due to the implementation's sociotechnical complexity.<sup>106</sup>

Most systematic reviews concluded that CDSS implementation is associated with improvements in the appropriateness of care, including:

- Better adherence to guidelines and use of preventive care
- Improved clinician–consumer communication

- Faster and more accurate access to EHR data
- Fewer medication errors
- Less unnecessary diagnostic testing
- Improved decision-making quality.<sup>8-11,60,81,83,85,102</sup>

However, the actual effect on patient outcomes was almost unanimously unclear.<sup>8,11,77,78,81</sup> For instance, one systematic review of CDSSs in diabetes care showed weak to modest associations with improved patient outcomes such as better glucose, lipid and HbA1c control. However, adherence to guidelines, process indicators and the quality of documentation led to significant improvements in care.<sup>10</sup> Likewise, in a systematic review of antimicrobial prescribing by Baysari et al., CDSSs were associated with improved prescribing appropriateness in six of eight studies.<sup>12</sup> CDSSs were also reported to reduce the number of pharmacy interventions and the use of broad-spectrum antimicrobials.<sup>12</sup> However, there were unclear effects of CDSSs on length of stay, adverse drug events and survival rates.<sup>12</sup> Similarly, CDSSs were shown to modify test-ordering behaviour in 75% of the studies, yet only 20% of the studies showed an effect on patient outcomes.<sup>85</sup>

Only a few systematic reviews provided evidence for a positive effect of CDSSs on specific patient outcomes. Specifically, CDSSs in ambulatory diabetes management were found to be associated with improvements in processes of care in 55% of included studies and patient outcomes in 63% of the studies.<sup>105</sup> In addition, CDSS implementation in depression management was reported to increase adherence to guidelines, and was associated with improved screening, diagnosis, referral and treatment.<sup>80</sup> The study also reported reductions in depressive symptoms and an increase in reported quality of life.<sup>80</sup> In cardiovascular care, CDSSs were found to be associated with moderate improvements in secondary prevention measures and slight reductions in the number of cardiovascular readmissions.<sup>83</sup> This review also found a significant reduction in acute myocardial infarction in people with coronary artery disease, but no significant results for the ongoing management of blood pressure.

EHRs, registries and other large datasets could improve decision support in the future. These analytical tools could extract relevant information and provide insights that clinicians can use to make evidence-supported decisions. Early research suggests that these resources have clinical value.<sup>107</sup> In addition, information about how other clinicians in the same specialty manage similar clinical cases can be included in future CDSSs. This CDSS functionality allows individual clinicians to learn from the evolving experience of colleagues as well as from the scientific literature, which may ultimately improve the safety and quality of care.<sup>71</sup> However, digital health interventions are limited by the amount and quality of data, and the level of commitment to change.

Alert fatigue is a notable factor influencing the effect of both CPOE and CDSSs. Alerts are intended to prompt appropriate care and mitigate risk. However, the excessive use of alerts is reported to be the most common barrier to a seamless workflow.<sup>5,16,53,54,57,59,61,63,64,66,67,100,101</sup> Alert fatigue and high rates of alert override are well-recognised consequences of frequent and irrelevant alerts.<sup>5,16,59,60</sup> This presents safety concerns when critical safety alerts are overridden.<sup>16,67</sup> Alert-override rates are also affected by how specific or detailed the information is. For example, clinicians were often overwhelmed by the complexity of

information in CDSS alerts and were then more likely to disregard the alert.<sup>60,69,71,85</sup>

Health service organisations may benefit from monitoring mechanisms to manage alert fatigue. Although there are ample vendor-supplied alerts, the literature recommends that organisations carefully review the inclusion of interruptive alerts and implement a minimum set of targeted alerts.<sup>5,60,61,66,69,71,85</sup> This particular approach was described by one key informant as a successful way to use CDSSs.

#### **Managing excessive alerts**

*One particular drug knowledge base was appallingly insensitive. We were having 1,600 alerts fire a month, our override weight and not changing was above 90%. It's firing before you order it. It's firing far too frequently. You just go through it and ignore it. Alert fatigue is what you've got.*

*I'd learned about two pharmacologists who wrote the bible on drug interaction checking. They created a process of where they went in and addressed only critical alerts and turned everything else off. We went from 1,600 and we got it down to just 320. And that was a huge win. The medical staff loved it. They looked at it and were just blowing through it.*

#### **Main findings and critical success factors:**

- CDSSs appear to be the most successful when implemented in combination with extra software components
- Interoperability of CDSSs with existing electronic systems may improve the success of their adoption and usability
- CDSSs that target decision support according to a local minimum set of indicators appear to have greater uptake and effect on quality of care.

## 5. Critical success factors common across digital health interventions

Elements of digital health that best support safety and quality, from both the reviewed literature and key informant interviews, were common across digital health interventions and not specific to any individual initiative. The key informants focused on elements of implementation as the principal success factor, when considering optimising the outcomes of digital health interventions. The reviewed literature also highlighted implementation processes as having a central role in influencing outcomes.<sup>90</sup> In fact, differences in implementation processes are attributed to diverse outcomes across similar digital health interventions implemented in different settings.<sup>54,63</sup> Given that digital health is a highly complex sociotechnical intervention, it is not surprising that implementation is a critical element for supporting positive patient outcomes. Yusof et al.<sup>108</sup> proposed a sociotechnical framework to evaluate the impact of digital health interventions through the concept of fit between human, organisation and technology.<sup>72,108</sup> According to this model, success and failure of a digital health intervention may be attributed to technology design, as well as to complex interplay between unique features of the environmental context in which the intervention is implemented.<sup>10,12,53,54</sup> The key informants also supported sociotechnical approaches to understanding implementation of digital health interventions.

### Sociotechnical approaches to change

*I think first of all that change has to be sociotechnical. In other words, you cannot simply take a technology and think that that technology is going to determine an improvement in quality or safety. The change is the change in services, the change in organisational culture, the change in the way things are done, the change in systems and processes, plus the change in the technology.*

Key informants were emphatic that implementation of digital health interventions is a highly complex phenomenon. Health service organisations face challenges when selecting which digital health intervention to use, and when aligning the multiple levels of complexity that come with using digital systems.<sup>109</sup> Attributing improvements in health care to digital health interventions is often difficult, due to their complex sociotechnical factors and context of the organisation.<sup>90</sup> This argument was echoed by one key informant who, when asked whether a digital health intervention improved safety and quality outcomes, commented that there was no straightforward answer.

### Do digital health interventions improve safety and quality outcomes?

*I think that's way too simplistic a question for a very complex program of work ... If you try to oversimplify these complex projects, you are not going to get to the bottom of it. Did it improve quality or safety? Of course it improved some aspects of quality, of course it improved some aspects of safety, but on the other hand there were both anticipated and unanticipated consequences and they played out differently in different circumstances. That's as good as it's ever going to get. There is no simple, straightforward answer.*

Implementation processes and environmental contexts are generally poorly described in the research literature.<sup>13,56</sup> This makes it difficult to make conclusive statements about the factors that make digital health interventions successful, and leaves policymakers and clinicians with poor empirical research to inform implementation.<sup>15</sup> The following sections of this report will

explore specific success factors related to implementation that support positive safety and quality outcomes, which are extracted from the literature and drawn from an analysis of key informant interviews.

## 5.1 Positive organisational leadership, governance, culture and resourcing

Although under-represented in the digital health literature, organisational factors have a strong bearing on the success of digital health interventions.<sup>72,110</sup> The available evidence emphasises the importance of leadership, governance and a positive organisational culture towards innovation.<sup>110</sup> Two key informants focused on the critical importance of organisational leadership in displaying commitment to, and belief in, the need for digital health implementation. Leaders need to support the necessary investment in implementation.

### The need for strong leadership

*Whoever is the boss has to be really committed, so it doesn't matter whether that's the minister or the secretary of the department, the CEO of the hospital. Whoever is the real boss of the project has to be completely committed and be involved. Otherwise, it's dead meat.*

*It almost seems surprising to me how much of a conversation there is to be had in some places [within the sector] about why this needs to happen. In every other place I've worked [outside the healthcare sector], it's just accepted that you're not going to be as good as you're supposed to be, as capable, as efficient, as competitive, if you're not digitising the way you work. So it needs support at the organisation's top level and drive to change the way they work, to focus it on safety and the right reasons, and to really back that change and invest in it. That leads the commitment to doing it and being crucial, and remains crucial to seeing it through.*

Appropriate governance systems and processes must be in place – at the organisation and program levels – to ensure successful outcomes.<sup>93</sup> Despite the considerable investment in people and time involved, key informants believed that strong program governance was essential and should not be compromised.

### The need for good governance

*You've got to make sure you've set up all the governance and committees that you need. You can't skimp on project boards, steering committees and reference groups. You can't skimp on how high those committees and levels of governance are. It's going to be the most expensive thing you do other than build a hospital itself but it's far more complex than building a hospital itself because you haven't done it as often. The governance has to report through to the board and the board should be interested in whether it's going well or not going well. You can't go, 'we'll get away with not having some elements of good project governance because we feel like we can do it cheaper or faster without all the right structure and people'. It's just not something you can skimp this time.*

Strong leadership and governance should be evidenced by management that has a clear understanding of the anticipated beneficial outcomes of the digital health intervention. In addition, objectives should be closely aligned with the health service organisation's existing goals and strategic priorities.<sup>110</sup> One key informant explained that carefully articulated objectives of a digital health intervention help to shape implementation plans that meet these objectives. This in turn increases the likelihood that positive gains are realised.

Strong leadership must also be demonstrated by appropriate investment in, and resourcing of, implementation. This includes allocation of funds for both the necessary technical and

human resources.<sup>93</sup> Key informants highlighted the need for dedicated implementation time, rather than expecting tasks to be absorbed into existing roles. One key informant called for appointment of a 'chief architect' role to oversee implementation. Another key informant highlighted that budgets may need to include allocated funds to backfill positions while workforce members attend training to support adoption.

## 5.2 Iterative, continuous improvement approaches

Implementation of digital health interventions is best supported by iterative approaches, which allow health service organisations to make progressive adjustments to digital health technologies and processes.<sup>90,93</sup> Continuous improvement approaches thereby improve the fit between the technology, human and organisational contexts<sup>110</sup>, and maximise the potential for digital health interventions to achieve improved patient safety and quality care. Organisations need to establish learning mechanisms that feedback information to improve future digital health iterations.<sup>111</sup> This knowledge helps decision-makers understand the unique characteristics of the context and how these affect implementation, and inform implementation strategies tailored to the local setting. The literature and the key informants identified different strategies to inform learning cycles.

### 5.2.1 Incorporate diverse perspectives in consultation

An important success factor was being able to harness the collective wisdom and experience of stakeholders in the design, implementation and problem-solving of digital health interventions.<sup>93,110</sup> The literature emphasises the need to consult different stakeholder groups, including consumers, clinicians, information technology (IT) professionals and management. This consultative approach ensures that interventions represent a good fit with end users and the organisational context, and informs patient safety and workflow issues.<sup>90,110</sup> Engagement and communication strategies may need to be tailored to stakeholder groups to maximise their involvement in learning and education.<sup>93</sup> To be most effective in supporting positive outcomes, such engagement should start early and be sustained over time.<sup>93,110</sup> Consultation facilitates dialogue and trust across stakeholder groups who may otherwise have diverse perspectives about digital health and use unique terminology to describe digital health interventions. Consultation thus provides an essential foundation for successful implementation.<sup>110</sup>

#### Facilitating dialogue around digital technologies

*If you get people from different worlds – the clinicians, the policymakers, the technical people, the commercial people – in the same room on a regular basis, it will be very, very awkward initially.*

*Nobody will want to talk to anybody else, but as they get to know each other, as they develop trust, as they begin to understand where the other stakeholders are coming from, you eventually get to a stage where you're making progress ... Any new technology needs to be talked about in an organisation and across organisations. You need to have what I might call town meetings, get people in a room, get them to voice their concerns, get them to try it out, get the people who are enthusiastic about the technology to talk to the people who are less enthusiastic, but also to hear the concerns of people who are worried about the technology because they may be right, and address them. All that soft stuff, the dialogue, the negotiation, is absolutely key to the success of the technology project ... In fact, I think it's more important than all of the hard stuff that people are always measuring.*

Wide stakeholder engagement also provides an opportunity to gain a deep understanding of the unique needs, concerns and viewpoints of users. These factors are considered to be essential to promote user acceptance of digital interventions. Failure to adequately consider user perspectives through stakeholder consultation and co-design processes may lead to:

- Negative original experiences with a digital health intervention
- Suboptimal acceptance and uptake
- Abandonment of the digital program.<sup>19,90</sup>

Ultimately, these could lead to a failure to achieve improvements in safety and quality.

Acceptance is directly correlated with the degree to which digital interventions are perceived to align with the specific needs and priorities of clinicians and consumers.<sup>3</sup> The ease of use of technology has a strong influence on the perceived value of digital health interventions.<sup>90</sup> If clinicians use a digital health intervention to promote patient safety and quality of care, they must see an advantage for using that intervention.<sup>15</sup> For example, the concept of relative advantage may explain why people with chronic conditions, or with intensive or long-term treatment regimens, appear more inclined to use electronic portals. Conversely, if consumers do not believe that portal functions are useful, they may be already satisfied with their clinician–consumer relationships, or, if they are not very ill, they may be less likely to see the extra benefit in using a portal.<sup>15,19</sup>

Stakeholder engagement provides an opportunity to identify user needs and concerns, and to tailor responses to these over time.<sup>90</sup> For example, one key informant commented on how consultation with clinicians enabled one organisation to deal with concerns about the appropriate timing of releasing potentially sensitive information.

#### Timing of releasing information to patients

*What was a big issue was when do you release information to the patients and how much do you release? Some pretty life-changing results come through and I think that's where, if there's good use of the portal and a patient sees that, they need a communication avenue without getting a clinic appointment, and to have an electronic dialogue. Some sites are actually paying for email and virtual consults.*

*Medical staff were concerned that they should be made aware of results ahead of the patient. We built in five days at this organisation. But over time, we shrunk that down and we expanded what we were releasing. So I think as people get more confidence in educating their patients, they've shrunk the release time and expanded what they are willing to publish out on the patient portal.*

Likewise, stakeholder engagement may help to ensure a good fit between users, and the design and usability of digital health technologies. Different user groups may not interact with technologies with the same ease or level of proficiency as other groups. The appropriate technology delivery platforms need to be matched to the target patient. User interfaces that are confusing or time-consuming may lead to errors in data entry, and retrieval and workarounds, potentially introducing new risks.<sup>90</sup> For instance, given that mobile technologies are prevalent across all populations, patient reminders delivered via text messaging appear to be an effective method of reaching underserved or difficult-to-reach populations.<sup>33</sup> The suitability of text message reminders for culturally and linguistically diverse communities, or for older people, requires further investigation.<sup>21</sup> Off-the-shelf technologies may need to be

personalised and tailored to specific user needs within certain settings.<sup>90</sup> One key informant described how engagement with clinicians has helped to identify critical usability issues with the provider portal of the My Health Record system. User feedback has informed adjustments to the portal design, to increase the functionality and the realisation of safety and quality outcomes. As the My Health Record system is accessed by clinicians through third-party software, a close relationship with these vendors is essential to the development of an interoperable system that meets user needs.

#### **Usability and the My Health Record system**

*The issue is that with those third-party vendors, it's more in their control what the clinician gets to see and how the system looks to them. The provider portal, unfortunately, is very under-utilised by the clinical community because of these other levels of security in place, which have prevented them from easily accessing it ... So we're working really hard with those third-party vendors to try and drive the way they improve the view of the My Health Record system through their system because that's what the impression that clinicians out there have of the system, because that's all they get. The other thing we're exploring is ways to easily allow clinicians to have access directly to the provider portals.*

The literature and key informant interviews identified the specific stakeholder groups that should be consulted as part of implementation of digital health interventions. Clinical leadership of digital programs was emphasised to ensure that clinical – not technological – perspectives drive solutions, which may help to promote optimisation of digital interventions.<sup>93</sup> One key informant emphasised clinician involvement in the implementation of electronic medication management systems.

#### **Drawing on clinical expertise to find solutions**

*There's no point just whacking in the electronic medication management system and hoping it will magically work everything out without official intelligence. You've actually got to put smart doctors and nurses and clinical pharmacologists around the table and say, 'Which alerts? We know there's alert fatigue if we put too many on, so which alerts are we going to leave on?'*

Local clinical champions can actively promote digital interventions, informing decision-making and strategy planning, and act as a bridge between IT professionals, clinicians and senior management.<sup>110,111</sup> Thus, clinician champions can strongly influence the success of an intervention. Clinical leadership may help to ensure that patient safety and quality outcomes are achieved, while supporting acceptability of digital interventions to clinical users. For example, one key informant emphasised the emerging and pivotal role of information officers in medicine, nursing or pharmacy to enable successful implementation and bridge the gap between clinicians and technology professionals. Another key informant recommended that health IT architects be hired as a way to incorporate health and IT perspectives in implementation plans, and to support clear communication and a shared understanding across sectors.

#### **Combining health and information technology perspectives**

*You hire a health IT architect. You don't hire a generalist IT architect. They're still struggling to understand why doctors are fussy halfway through the program – 'Why are the doctors so difficult to work with?' – whereas a good health IT architect speaks the same language and understands what the doctors and the nurses are trying to ask for.*

Networks – such as those between organisations, vendors and users – may support learning cycles.<sup>90</sup> Networks provide an opportunity to share experiences about implementation and

learn from others' experiences of using digital health interventions, rather than having a narrow focus on 'what works'. Similarly, a key informant reported that one country used a strategy that supported local approaches to digital health maturity. Here, health service organisations were encouraged to collaborate in the development of action plans at a regional level. Such strategies may help to form networks for sharing knowledge, thus driving sustained improvements in the uptake of best-value elements of digital health across the sector.

#### **Networks for promoting uptake of best-value digital health strategies**

*We're also expecting them to make progress, not just within their own organisation, but on a more local, regional basis, through sharing data more readily and easily across their local partners, the care providers, and also with primary care and potentially social care. So, information sharing within that local economy, and the use of technical standards and solutions to support that. What we're not doing is trying to create digital islands. The key focus is that then ultimately you'll be able to go into these organisations and see them working paper free as much as they can, but it goes beyond that.*

### **5.2.2 Using data to improve safety and quality**

The ability to use data immediately in quality improvement cycles is also an important way to maximise patient safety and quality outcomes. Using data this way can inform adjustments to digital health interventions during implementation. Digital platforms such as electronic healthcare records (EHRs), computerised physician order entry (CPOE), clinical decision-support systems (CDSSs) and electronic patient portals provide ways to collect data. These platforms may also help to quickly identify patient safety and quality issues, and then develop strategies to deal with them.<sup>93</sup> For instance, one key informant described using EHRs and CPOE to identify and deal with a patient safety issue – an excessive demand for services from infusion centres due to increased volume of orders.

#### **Using electronic health records and computerised physician order entry to identify and deal with patient safety issues**

*Tracking involves three phases basically. Looking at who's using it, and the volume and how often they're using it. That's physicians and nursing. Then looking at the chains of workflow and getting a report around that. That was the key thing. We had printed reports with the chemo infusion orders, and were worried if we'd have a backup in the infusion centres, so we put metrics around that and we even got a contingency plan. Our team – which was myself, some IT people, pharmacists, nursing staff, medical staff – we'd try to solve it and if it got even worse, it would go up to executive leadership.*

Data can also be used to consider unsubstantiated user concerns about digital health interventions, by providing the evidence necessary to support development of positive attitudes towards a plan. For example, in describing the implementation of a new decision rule in a hospital setting, one key informant described the use of data generated by EHRs and CDSSs as a way to directly address clinician concerns.

#### **Using data to support attitude change towards digital health interventions**

*The people in key positions got frustrated with the false positives, but it was an opinion. And then we got the data of the number of false positives and, well, 'We understand your opinion, but here's the raw, irrefutable data in your unit', and turned her to become an advocate.*

Digital health interventions have the potential to enable access to data that could be used to promote safety and quality outcomes. However, it is essential to ensure that the necessary policy infrastructure is in place to realise this potential. For example, one key informant spoke

of the potential of data in the My Health Record system to improve patient safety and quality of care. However, there is a gap in the models that would allow the data to be used in this way.

#### **The potential of data in the My Health Record system**

*If we had a framework that allowed us to use the data in the My Health Record system for secondary purposes, we could improve our understanding of the way systems could be run more efficiently. We could look at the way the system could support us to predict where medication errors might be going to occur. We could avoid those errors from happening. We could avoid unnecessary hospital admissions through a medication error, and things like that. There's a lot of ways that the information in the system could be more cleverly used, operating in a safer way, operating in a more efficient way, and operating so that people get better health outcomes.*

### **5.3 Attention to workflow**

The impact of digital health interventions on workflow is a critical factor in improving positive safety and quality outcomes.<sup>90</sup> Well-integrated CPOE systems, for instance, had the strongest evidence for:

- Significantly increasing clinicians' adherence to guidelines
- Increasing the appropriateness of disease and treatment monitoring
- Optimising medication use.<sup>60</sup>

Thus, these systems may have an indirect effect on safety and quality outcomes. Yet, for many health service organisations, the effects of digital health intervention implementations on workflow and efficiency have not been well assessed. For instance, a lack of harmonisation of digital health interventions with clinical pathways and existing systems may disrupt workflow.<sup>63,64</sup> This in turn could lead to adverse effects on usability, accentuated implementation complexity and reduced patient safety.<sup>54,67</sup> Secure messaging between consumers and clinicians has the potential to improve patient safety and quality, but may concurrently increase clinicians' workload considerably, and impede their ability to respond to consumer messages on time<sup>13</sup>, a potential risk to patient safety. Key informants concurred that digital health interventions must be integrated into workflow to support uptake and, ultimately, to achieve positive outcomes.

#### **The My Health Record system and integration with workflow**

*You can imagine in a busy [general practitioner's] life, you just don't have a lot of time to be jumping out of your clinical information system and onto a website somewhere, and entering data. You need it to be seamless. The reality of the situation is that the majority of clinicians only see the thing through their medical practice, whatever it is that the hospital interface has got set up.*

Key informants also cited examples when integration of digital interventions with workflow were critical success factors in achieving positive patient outcomes. For example, one key informant described the interaction between a new CDSS rule and clinician workflow, and how these were successfully addressed through learning cycles and immediate use of data in continual improvement cycles.

### Integration of a clinical decision-support system with workflow supports positive outcomes

*We created a clinical decision rule for sepsis. In that organisation, we reduced the mortality from sepsis. When I was here in 2014, I looked at Australian figures and it was below 30%, but we moved it down to the low teens in my organisation. It's been replicated across the world.*

*I saw break points in the workflow that would stop patients getting treatment in a timely way. The technology is part of it, but it's the process and the people aspect, as well. You've got to have an accurate and sensitive alert, but you've got to have somebody who picks it up. We realised that we hit a plateau below 30%, because people were missing their alerts. Nurses were entering vitals, writing on a sticky note, and putting it in at the end of their shift. They needed to do this in real time. There are learning curve things. Have you got the right data input devices? Are there enough devices? Are there portable devices? I mean, why are they writing on paper?*

*We realised that the EHR [electronic health record] was not the optimal vehicle. I think we got it below 30% when the alert fired, but you're looking really at [intensive care unit] or [emergency department] patients, and people are busy in these areas. They're high intensity care areas. So we formed an immediate response team.*

*But thinking someone's going to sit at a PC all day, waiting for an alert to fire won't work. They're taking care of patients, they don't have time to sit and look at the screen for an alert to fire. So we then have to look at an alternative communication modality, and that was using pagers that were automated from the source criteria, using that technology beyond the EHR. So, you'd pick up early pre-sepsis, engage the immediate response team to go out and assess the patient, and then institute sepsis protocols for treatment, including a [key performance indicator] that the patient would be assessed within 30 minutes. That was the sequence of how we kept, stepwise, getting better mortality rates.*

Changes in workflow may have implications for the physical environment of organisations. Physical environments may inhibit or promote the use of digital interventions.<sup>19</sup> The literature recommends that, when implementing digital health interventions, the availability and placement of workstations according to workflow should be considered. This was especially apparent in reviews of CPOE in emergency departments and intensive care units, in which appropriately placed workstations facilitated efficient medication ordering.<sup>16</sup> Similarly, key informants reported that integration with workflow may demand changes to the physical environment, which highlights the role of important stakeholders in identifying appropriate solutions.

### Digital health interventions and the physical environment

*As they think through that, they realise, 'Oh my god, we're changing our model of care. We're going to change the way we do medication ward rooms. We're going to change where the pharmacist looks at the meds information, makes advice, we have it that they phone the resident'. It changes how the resident then make a change after the pharmacist phones them to say we want a change, and so the whole process starts changing. It's not pick up the bit of paper from the out tray in the ward. And so they now revise their model of care.*

*In relation to the digital architecture, you've got to change physical aspects of the hospital. I think having all the right people to think through, oh, so now the way we work is going to be like this, and that may mean ripping out nurses' stations and putting in places, putting in bench seats with places to wheel your laptop and plug it in and making sure you've got dense enough wi-fi in that spot and all that sort of good stuff.*

## 5.4 Multifaceted digital health strategies

Given the complexity of clinical care, it appears simplistic to expect that an isolated digital health intervention will have a large positive effect on patient outcomes.<sup>31</sup> The literature emphasises the importance of using a multifaceted approach to the implementation of health

technologies, including educational and training support, tailored alerts, and decision support to further improve the safety and quality of care.<sup>9,10,52,66,102</sup> Targeted education and training support before and during implementation has been reported as a contributing factor for increased adoption and quality of care.<sup>52,63,90,112</sup> More intensive approaches were reported to result in greater improvements to quality of care. For example, CPOE implementation combined with reminders, performance feedback, educational modules and workflow redesign, and the implementation of complementary decision support tools resulted in the most positive outcomes.<sup>8-13</sup> Key informants supported the implementation of multifaceted digital health interventions as a way to achieve the most improvements to patient safety and quality. One key informant highlighted that multifaceted implementation was a feature of exemplar digital projects.

#### **Combining digital technologies**

*I think it needs to be about how we can combine different capabilities, different technical solutions and addressing issues of wasted health resources. Again, I think that previously in the past there's maybe been a focus on doing it in slightly isolated components and then expecting them to kind of do any kind of significant connecting. You need to put those things together, and it drives improvements in that area.*

## 6. Existing approaches to measuring digital health

As governments continue to invest heavily in digital health systems, a coordinated and standardised approach to appropriate investment, design and implementation is essential to achieving national priorities.<sup>96</sup> To inform a best-practice approach, a systematic measurement of digital health interventions is needed. This would allow a knowledge base to be created, from which the most cost-effective, safe and scalable interventions for improving patient outcomes can be identified.<sup>113</sup>

Evaluations of digital health present specific challenges. As highlighted by this report, the different digital health interventions make it difficult to draw strong conclusions from the literature. Additionally, cultural barriers, data collection, associated costs and a rapidly evolving sociotechnical environment also impede effective measurement.<sup>90</sup> Also, a number of factors might contribute to evaluative findings going unpublished.<sup>114</sup> Conflict of interests can, in particular, make it difficult to publish negative findings<sup>114</sup>, which means that the potential for publication bias should not be underestimated in this discipline.<sup>115,116</sup> Therefore, the existing evidence base is often of little value to decision-making.<sup>117</sup>

In the current literature, systematic evaluations of digital health are few, and remain an area of ongoing research.<sup>118</sup> Internationally, health service organisations and governments have begun to develop different approaches to measuring digital health. Although varied, these approaches each involve structural, process or outcome measures, such as that in Donabedian's framework for quality of care.<sup>119,120</sup> The following sections explore existing approaches to digital health measurement for organisations.

### 6.1 Structural measurement

As defined by the Agency for Healthcare Research and Quality<sup>120</sup>, structural measures evaluate an organisation's capacity and systems. Using structural measures to evaluate digital health often includes the evaluation of the health service organisation's digital maturity according to its readiness, capabilities and infrastructure. Structural measures can be conducted at organisational level or for system-wide comparison.

This type of measurement is especially important, because there are large inconsistencies in digital maturity across health service organisations globally and in Australia. Although there are pockets of excellence for the uptake of digital health, the extent of adoption is highly variable. This represents a critical source of inequity in care delivery. Key informants acknowledged the growing variation in digital health maturity across organisations.

*I see a great variation across the country. Despite a very significant national program that made some progress a few years ago, we ended up with this clear group towards the top end who are largely digitised, those who have certainly deployed most of technology in parts or most of their organisation, and are kind of finishing the job in those essential areas and at the same time moving on to the more advanced stuff. And then there are a significant majority in the middle who have parts of it, maybe some bits but not across their entire organisation. And then equally a significant number here are quite*

*far behind and still heavily relying on paper-based or certainly at best hybrid systems of process across those key areas.*

In the first phases of measuring digital maturity, baseline measurements are fundamental.<sup>121</sup> Self-assessment and benchmarking are considered an important method to:

- Establish the current state of digital health across organisations
- Identify areas of relative strength or weakness within the organisation
- Identify the degree of consistency or variation in digitisation between organisations.

These measures provide a baseline to identify considerable gaps for prioritisation and planning.<sup>88,90</sup> Some informants identified that a key future direction of digital health is to ensure consistency and reduce variation in care though increased access, uptake and use of digital platforms.

*By doing the self-assessment, we wanted to gain an insight nationally into how everyone's doing and what the big gaps are. At a national level, we've had a few main conclusions that we have taken from it, and then we're looking to address these.*

*We need to try to get a good tool in to everybody; device integration, meds decisions, and a good design integrated across the entire health system.*

The weakness of structural measurements is its primary focus on measuring functionality as opposed to measuring patient outcomes. As demonstrated in this report, a health service organisation may implement a CDSS, but have a high alert-override rate, resulting in limited benefit to quality of care. In comparison, another organisation may implement a CDSS in only one department, but show clinically significant benefits. A purely structural measurement approach would consider the first organisation to be more digitally advanced, regardless of whether the effects on patient safety and quality are negligible.

## 6.2 Process measurement

Process measurement is the measurement of the proportion of health care that is recommended or aligns with best-practice guidelines. Process measures evaluate the specific steps in a process that lead to either a positive or negative outcome.<sup>120</sup> In digital health, process measures are specifically related to the design, implementation and use of digital health interventions.<sup>89,90,122</sup> Process measures typically acknowledge the sociotechnical factors involved in the success of an intervention.<sup>90</sup> Singh and Sittig posit that digital health measurement must be considered in the context of relevant sociotechnical factors.<sup>123</sup>

As opposed to structural measures, process measures are intrinsic to the digital health intervention and provide intervention-specific insights, rather than an overview of an organisation or system. As discussed in the implementation section of this report, process measures can, therefore, be used in an iterative development process or to monitor the intervention progress.<sup>90</sup> This method involves collecting and analysing data to work out if the intervention is being implemented as expected at multiple time points.<sup>91</sup> The knowledge gained from this process can inform decisions on how to optimise content and implementation of the system.

## 6.3 Outcome measurement

Outcome measures reflect the effect of the intervention on the person, population or organisation that is the target of the intervention.<sup>124</sup> These measures may include clinical outcomes, person-centred outcomes, and resource use and economic outcomes.<sup>125</sup>

Attributing outcomes to the intervention can be an especially difficult component of digital health measurement. Outcome measures should therefore be linked to the defined problem, population or health need that the digital health intervention is intended to consider.<sup>113</sup>

Outcome measures can be self-assessed and benchmarked at multiple time points, and compared with organisational performance indicators, published benchmarks, and regional, national or international performance rates. Assessment and benchmarking can be used in a continuous quality improvement cycle to identify areas that require attention and improvement. It also help to realise benefits and how they could be achieved under comparable circumstances.<sup>93</sup>

One key informant described the measurement of patient outcomes attributed to the implementation of CDSS alerts for sepsis risk and management. In the first phases of the program, sepsis was identified as a significant life-threatening condition that was difficult to detect, yet relatively simple to treat. The CDSS alerts aimed to help clinicians accurately and quickly identify those with the condition.

*The algorithm fires the alert saying, 'This is early sepsis, or could be early sepsis. This patient needs to be assessed. I'm putting in a PKI [protein kinase inhibitor] that will be assessed within 30 minutes.' This reduced the mortality from sepsis. I looked at Australian figures and it was below 30% and my organisation moved it down to the low teens ... It was saving lives ... Now it's being replicated across the world.*

Other examples of outcome measures include length of stay, readmission rates and allergic reactions. A clear definition helps to focus a measurement plan, so that the data generated can be used to assess causal relationships between the digital health intervention and expected outcomes.

## 6.4 Example measurement models

Selecting the appropriate measurement factor (structural, process or outcome) will better measure how health IT might be used to improve patient safety, quality of care and health outcomes. This is especially important when seeking to attribute outcomes to a digital health intervention. The three example models below have adopted structural, process or outcome measures, or a combination of the three.

### 6.4.1 NHS Digital Maturity Index

An example of self-assessment and benchmarking of structural measures is the National Health Service (NHS) England Digital Maturity Index (DMI)<sup>88</sup>, a model that assesses organisational readiness, capabilities and infrastructure (Table 2). A informant described this national approach to measurement as a way to help identify the main capabilities that could be digitised.

In 2015, NHS organisations were instructed to conduct a self-assessment. The intent was to establish a baseline measurement to develop Local Digital Roadmaps (LDRs) within each local region. The development of LDRs set clear expectations on how to increase digital maturity, focus discussions and help best-practice decisions. NHS aggregated the individual self-assessments into the DMI to benchmark relative progress against peers.

The benchmarking of these data enabled the sharing of learning and collaboration between organisations. Organisations were able to use their self-assessments to identify shared goals with other organisations within a region and develop action plans. Following benchmarking activities, exemplar regions that were considered digitally advanced applied to show how they would use funding to drive a larger effect across the sector. Selected regions were funded to advance them further, and help them to become a blueprint for exemplary digitalisation in the NHS. The goal of the blueprint is for other organisations to understand and learn from those who have optimised and exploited what is often the same main technology to deliver a higher level of benefit.

**Table 2: The NHS Digital Maturity Index**

Section	Subsections	Descriptions
Readiness	<ul style="list-style-type: none"> <li>• Strategic alignment</li> <li>• Leadership</li> <li>• Resourcing</li> <li>• Governance</li> <li>• Information governance</li> </ul>	An assessment of the organisation's ability to plan, deliver and optimise the digital systems it needs to operate paper free at the point of care
Capabilities	<ul style="list-style-type: none"> <li>• Records, assessments and plans</li> <li>• Transfers of care</li> <li>• Orders and results management</li> <li>• Medicines management and optimisation</li> <li>• Decision support</li> <li>• Remote and assistive care</li> <li>• Asset and resource optimisation</li> <li>• Standards</li> </ul>	An assessment of the availability, extent and optimisation of digital capabilities across an organisation
Infrastructure	n/a	An assessment of the underpinning infrastructure to support delivery of these capabilities

n/a = not applicable

## 6.4.2 World Health Organization's Monitoring and Evaluating Digital Health Interventions

An example of a guide to self-assessment is the World Health Organisation's (WHO's) *Monitoring and Evaluating Digital Health Interventions: A practical guide to conducting research and assessment*.<sup>118</sup> The self-assessment combines structural, process and outcome measures. WHO suggests measurement should be linked to the digital health intervention stage of maturity (Table 3).

This approach includes measurement methods for the:

1. Monitoring of intervention deployments, focusing on the quality and fidelity of the intervention inputs
2. Evaluation of intervention outputs and impacts across many axes, from user satisfaction to process improvements, health outcomes and cost-effectiveness.

**Table 3: Linking stages of intervention maturity with measurement and objectives**

Time frame	Stage of maturity	Stage of evaluation	Aims
Early	<ul style="list-style-type: none"> <li>• Pre-prototype. This stage includes hypothesis-building, needs/context assessment, and testing of usability/feasibility and technical stability.</li> <li>• Prototype. During this phase, user-focused designs are created and tested, and functionality, technical stability, and usability are tested in an iterative process. Ways to improve the system are examined to enhance relevance.</li> <li>• Pilot. This stage examines whether the digital health intervention can produce the desired effect under controlled circumstances. The pilot project is usually a single deployment.</li> </ul>	<ul style="list-style-type: none"> <li>• Feasibility. Assess whether the digital health system works as intended in its given context.</li> <li>• Usability. Assess whether the digital health system can be used as intended by users.</li> <li>• Efficacy. Assess whether the digital health intervention can achieve the intended results in a research (controlled) setting.</li> </ul>	<ul style="list-style-type: none"> <li>• Technology. Prototypes are functional and usable. Feasibility testing demonstrates user acceptance, and expected data integrity and validity.</li> <li>• Intervention. Implementation protocols are used as intended by users.</li> <li>• Technology. Technology withstands testing under optimal circumstances.</li> <li>• Health. Health improvements (outputs/outcomes/impact) demonstrated on a small scale, under optimal circumstances, warranting further testing.</li> </ul>

Time frame	Stage of maturity	Stage of evaluation	Aims
Middle	<ul style="list-style-type: none"> <li>• Demonstration. In this stage, the intervention is no longer taking place in controlled conditions, but is still limited in terms of population/geography (usually restricted to a region or subregion). This stage seeks to understand the costs and implementation requirements needed to both deliver the intervention at high fidelity and replicate the uptake in new contexts.</li> </ul>	<ul style="list-style-type: none"> <li>• Effectiveness. Assess whether the digital health intervention can achieve the intended results in a non-research (uncontrolled) setting.</li> </ul>	<ul style="list-style-type: none"> <li>• Health services delivery at moderate-scale implementation in a non-research setting is determined to be feasible, high quality and cost-effective, improving the effectiveness of bringing about positive change in health outcomes.</li> </ul>
Advanced	<ul style="list-style-type: none"> <li>• Scale-up. In this stage, approaches are ready to be optimised and scaled up across multiple subnational, national or population levels.</li> <li>• Integrated and sustained program. Efforts at this stage are focused on determining the necessary components of an enabling environment that will support impact of the intervention at a large scale (e.g. policies, finance, human resources, interoperability). The intervention has been integrated into a broader health system.</li> </ul>	<ul style="list-style-type: none"> <li>• Implementation science. Assess the uptake, integration and sustainability of evidence-based digital health interventions for a given context, including policies and practices.</li> </ul>	<ul style="list-style-type: none"> <li>• Technology is functional and being effectively implemented at scale.</li> <li>• Support systems are in operation to ensure continuous service provision.</li> <li>• Health services delivery at large-scale implementation through integrated service delivery is determined to be feasible, high quality and cost-effective, improving the effectiveness of bringing about positive change in health outcomes.</li> </ul>

### 6.4.3 National Quality Forum Health Information Technology Measurement Framework

The last example is the National Quality Forum Health Information Technology Measurement Framework.<sup>90</sup> This model suggests nine key measurement areas for digital health (Table 4). Each area includes several process measures that could reflect performance in that area, and possible data sources or data collection strategies for each area. This model is an adaption of the Health IT Safety Framework<sup>126</sup>, is based on the sociotechnical environment of

digital health implementation, and reflects structural, process and outcome measures.

**Table 4: National Quality Forum Health Information Technology Measurement Framework**

Measurement area	Example of process measure
Quality of clinical decision support	Percentage of alerts that occur at the right time, for the right person, in the right context, and are useful
System interoperability	The extent to which meaningful external data are available to make diagnosis or management decisions (e.g. percentage of completed transactions between any two systems)
Patient identification	Percentage of potential duplicate patients in the EHR
User-centred design, and use of testing, evaluation and simulation	End user involvement in life cycle (design, development, implementation, use, evaluation) of HIT (e.g. how participants are selected and how many are involved)
System downtime (data availability)	Percentage of system uptime or availability (ideally, more than 99.9%)
Feedback and information sharing	Free and transparent bilateral exchange of information about real-time user experiences, and issues with HIT design and implementation
Use of HIT to enable timely and high-quality documentation	Discharge and transition summary quality (e.g. reason for referral) and completeness
Patient engagement	Percentage of patient portals that include viewable patient progress notes
HIT-focused risk-management infrastructure	Formal processes for evaluating and responding to risks

EHR = electronic healthcare record; HIT = health information technology

## Appendix A Glossary

Term	Acronym(s)	Definition
<ul style="list-style-type: none"> <li>benefits realisation</li> </ul>	none	The final phase of a program that is a report and comparison of the benefits achieved compared with those targeted.
<ul style="list-style-type: none"> <li>clinical decision-support systems (MeSH)</li> <li>computer-assisted decision-making (MeSH)</li> <li>computerised decision-support systems</li> <li>computer-assisted image interpretation (MeSH)</li> </ul>	CDS; CDSS	An electronic system aimed to support clinical decision-making, linking patient-specific information in electronic records with evidence-based knowledge to generate case-specific guidance messages through a rule or algorithm-based software. This includes computer-assisted diagnosis and therapy systems.
<ul style="list-style-type: none"> <li>computerised medical record system (MeSH)</li> <li>computerised patient record</li> <li>electronic clinical information system</li> <li>electronic medical record</li> <li>electronic patient record</li> </ul>	EMR; EPR	An electronic system for input, storage, display, management and retrieval of clinical related information by authorised clinicians and workforce members. These record systems may enable transportability of information across the care continuum within the internal hospital system. Some versions include integrations with several software components and specialty-specific extensions. For example, electronic record for intensive care, incident information management system and endoscopy information system.
<ul style="list-style-type: none"> <li>electronic healthcare record</li> </ul>	EHR	An electronic system that operates as a patient-centre repository of information used across varied health service organisations.
<ul style="list-style-type: none"> <li>electronic discharge summary</li> <li>electronic patient</li> </ul>	EDS	A summary that serves as the primary documents communicating a patient's care plan to the post-hospital care team.
<ul style="list-style-type: none"> <li>electronic medication management</li> <li>patient medication record</li> </ul>	EMM; eMeds	An electronic system, tool or software application that supports the medication management cycle, including: <ul style="list-style-type: none"> <li>Prescribing systems</li> <li>Decision support systems, such as evidence-based order-sets, allergy checking, drug interactions</li> <li>Dispensing systems, such as pharmacy software and automated dispensing systems.</li> </ul>
<ul style="list-style-type: none"> <li>electronic prescribing</li> <li>e-prescribing</li> <li>electronic transmission of prescriptions</li> </ul>	none	An electronic system used to review medication information and transmit prescriptions to a printer, electronic record or pharmacy. Electronic prescribing software can be integrated with existing electronic information systems to enable exchange of patient-specific medication information between clinicians and organisations in primary care and community pharmacies.

Term	Acronym(s)	Definition
<ul style="list-style-type: none"> <li>• electronic referral</li> <li>• eReferral</li> </ul>	none	An electronic system for creating, storing and sharing referral reports used to support the seamless exchange of patient-specific information from one treating clinician to another.
<ul style="list-style-type: none"> <li>• health information exchange (MeSH)</li> </ul>	HIE	The dissemination of electronic healthcare information or clinical data, across health service organisations.
<ul style="list-style-type: none"> <li>• health smart card</li> </ul>	none	A hand-sized card with a built-in computer chip used for accessing, storing and protecting consumers' healthcare information.
<ul style="list-style-type: none"> <li>• hospital information system (MeSH)</li> <li>• multi-hospital information system</li> </ul>	HIS	A hospital-wide integrated, electronic system designed for input, storage, display and management of all the aspects of a hospital's operation, such as medical, administrative, financial and legal, and the corresponding processing of services. HIS often comprises one or several software components with specialty-specific extensions, as well as many subsystems in medical specialties from a multi-vendor market. Some HISs can be implemented across multiple hospitals within in an area, known as 'multi-hospital information systems'.
<ul style="list-style-type: none"> <li>• interactive health communication applications</li> </ul>	IHCAs	A computer-based, usually web-based, information package for consumers that combines health information with at least one of social support, decision support or behaviour change support.
<ul style="list-style-type: none"> <li>• medical informatics applications (MeSH)</li> </ul>	none	An automated system applied to the patient care process, including diagnosis, therapy, and systems of communicating medical data within the healthcare setting.
<ul style="list-style-type: none"> <li>• medical order entry system (MeSH)</li> <li>• computerised provider (or physician) order entry</li> <li>• medication alert system</li> </ul>	CPOE	An electronic information system, usually computer-assisted, that requires clinicians to directly order medical procedures and tests, and prescribe medicines. The system then transmits the order directly to the recipient responsible for carrying out the order.
<ul style="list-style-type: none"> <li>• medication reconciliation</li> </ul>	none	The process of: <ul style="list-style-type: none"> <li>• Obtaining and clinically verifying a complete and accurate list of each patient's current medicines</li> <li>• Matching the medicines the patient should be prescribed to those they have been prescribed.</li> </ul>

Term	Acronym(s)	Definition
<ul style="list-style-type: none"> <li>medication-related reporting</li> </ul>	none	A set of medication-related information extracted from one or more sources and converted into a report to meet statistical, safety and quality, epidemiological, government or regulatory requirements.
<ul style="list-style-type: none"> <li>My Health Record system</li> </ul>	none	A shared EHR available for any Australian. The My Health Record system was developed and is operated by the Australian Digital Health Agency. Consumers and clinicians can send and view different documents via the system, either as an EHR, or through the government portal.
<ul style="list-style-type: none"> <li>patient portal (MeSH) personal health portal</li> </ul>	none	A secure online website that provides consumers convenient 24-hour access to personal health information.
<ul style="list-style-type: none"> <li>personal health record</li> </ul>	PHR	A collection of health-related information that is documented and maintained by the individual it pertains to. EHRs may include access to PHRs, which makes individual notes from an EHR readily visible and accessible for patients.
<ul style="list-style-type: none"> <li>picture archiving and communication system</li> </ul>	PACS	A healthcare technology for the short- and long-term storage, retrieval, management, distribution and presentation of medical images.
<ul style="list-style-type: none"> <li>reminder systems (MeSH)</li> <li>patient prompts</li> <li>patient reminders</li> <li>computer reminders</li> </ul>	none	An electronic system used to prompt or aid the memory of clinicians and consumers, or anticipate health events. The system uses reminders, colour coding, prompts and telephone calls.
<ul style="list-style-type: none"> <li>shared health summary</li> </ul>	none	A clinically reviewed summary prepared by an individual's main clinician.

# Appendix B Search strategy

## Question

1. What elements of digital healthcare programs have improved the safety and quality of health care?
2. What are the approaches to measure and benchmark the uptake and impact of digital healthcare programs?

## Purpose

The purpose of this scoping review is to obtain a detailed understanding of the broad literature base that addresses the following project objectives:

## Objectives

1. Identify and define the elements of effective digital healthcare programs, including:
  - a. Primary goals
  - b. Delivery platforms
  - c. Development paths
  - d. Tools, processes and workflows
  - e. Target patient populations and health conditions
  - f. Types of health data utilised
2. Identify barriers and enablers to implementation of digital healthcare
3. Identify approaches to measure and benchmark the uptake and impact of digital healthcare programs.

## Overview

We will undertake a search of terms associated with four selected digital healthcare types as agreed by the project working group on 9 June 2017. Each digital healthcare type will be investigated for its impact on safety and quality and barriers/enablers to successful implementation, using several databases, hand searches of key journals, using the snowball method and citation tracking via a search of the grey literature. A list of search terms is presented in the mind map below. We will use the following search terms and Medical Subject Headings (MeSH). This search strategy was based on Cochrane Review recommendations.

## Search terms

Digital Health Type 1: Clinical Decision Supports:

- TS: (Clinical OR Health\* OR Medic\*)
- TS: (Computer\* OR User-Computer Interface OR Digital OR Electronic\* OR Technolog\*)
- TI: (Decision Support\* OR Clinical Decision)

- TI: (Patient Safety OR Quality of Health Care OR Outcome OR Impact)

Digital Health Type 2: Electronic patient portals including patient prompts and reminders:

- TS = (Clinical OR Health\* OR Medic\*)
- TS = (Computer\* OR User-Computer Interface OR Digital OR Electronic\* OR Technolog\*)
- TI = (portal OR patient portal OR patient web portal)
- TS = (safety OR quality OR outcome OR impact OR effect)
- TS = (Clinical OR Health\* OR Medic\*)
- TS = (Computer\* OR User-Computer Interface OR Digital OR Electronic\* OR Technolog\*)
- TI = (remind\* OR prompt\*)
- TS = (safety OR quality OR outcome OR impact OR effect)

Digital Health Type 3: Electronic discharge summaries:

- TS = (Clinical OR Health\* OR Medic\*)
- TS = (Computer\* OR User-Computer Interface OR Digital OR Electronic\* OR Technolog\*)
- TS = (safety OR quality OR outcome OR impact OR effect)
- TI = (electronic\* OR technolog\* OR digital OR online OR web OR computer\*)
- TS = (discharge AND summar\*)

Digital Health Type 4: Computerised provider order entry:

- TS = (Clinical OR Health\* OR Medic\*)
- TI = (CPOE OR computerised provider order entry OR computerised physician order entry OR ePrescribing OR electronic prescribing)
- TS = (Safety OR Quality OR Outcome OR Impact OR Effect\*)

## Bibliographic databases

The literature search will be conducted using Web of Science, CINAHL and Cochrane databases.

## Hand search of journals

*Quality and Safety in Health Care*

*International Journal of Quality in Health Care*

*International Journal of Digital Healthcare*

*The Journal of mHealth*

*Journal of Medical Internet Research*

## **Grey literature**

To retrieve supplementary relevant grey literature, we will consult the main state, national and international digital healthcare organisations. Extensive Google searches will be conducted using the above listed search terms to retrieve relevant grey literature.

## **Inclusion and exclusion criteria**

We will exclude studies that 1) are based on patient perspective; or 2) did not provide sufficient details in methods and results sections.

## **Date range**

The initial search will incorporate results published in the 5-year period, 2012–2017. Publications dated pre-2012 may be retrieved and included in the final report if considered to be seminal work and/or of significant impact.

## Appendix C Interview script

*Thank you for agreeing to be interviewed today. We're really interested in your experiences and thoughts about implementing digital health initiatives, so we appreciate the time you've given. As mentioned in the email invitation and consent form, we will digitally record our conversation today so that we can review your comments in detail to extract key themes. The recording will be stored securely and will only be available to others within the research team. Before we proceed, do we have your permission for that?*

**Context: The following questions will help us to understand your role in digital health**

How have you been involved in any digital health initiatives? (i.e. selection, development, implementation, review or consultation)

What types of digital health have you had experience with? (i.e. platforms, primary goals, target population, types of organisations)

**Case study: The following questions will explore key learnings from specific digital health initiatives that you have experience with**

How/why did your organisation select that digital health initiative? How was the digital health initiative developed?

How was the digital health initiative implemented? (i.e. processes, key stakeholders delivery platforms)

How was the digital health initiative reviewed/assessed? Was the digital health initiative successful? (why/why not?)

Did the digital health initiative improve safety and quality outcomes? If yes, in what ways? What were the success factors/enablers?

What were the barriers? How were they addressed? Reflecting on your experience, what are your key learnings?

What you recommend to others who might be interested in a similar digital health initiative?

**Benchmarking (if relevant to participant): The following questions relate to the self-assessment, monitoring, and benchmarking of uptake of digital health initiatives:**

How does your organisation self-assess, monitor, and benchmark uptake of digital health initiatives?

In self-assessment, monitoring, and benchmarking digital health, what has worked well? Why?

In self-assessment, monitoring, and benchmarking digital health, what hasn't worked so well?

Why?

What impact has self-assessing, monitoring, and benchmarking had on the organisation?  
Please give an example

What are the indicators of a digitally mature health system?

**Future of digital health: The following questions will explore your opinions on the opportunities and challenges facing the digital health sector**

What impact has the implementation of digital health initiatives had on the overall patient safety and quality?

What could be improved in digital health? (i.e. weaknesses)

What opportunities are present for digital health? (i.e. what is missing from the sector that could be done?)

What are the challenges in achieving in realising these opportunities?

*If you had a magic wand (money, resources, eliminated barriers) what would you do in digital health to improve patient safety and quality*

## References

1. Coughlin SS, Prochaska JJ, Williams LB, Besenyi GM, Heboyan V, Goggans DS, et al. Patient web portals, disease management, and primary prevention. *Risk Management and Healthcare Policy* 2017;10:33–40.
2. de Lima ICV, Galvão MTG, de Oliveira Alexandre H, Lima FET, de Araújo TL. Information and communication technologies for adherence to antiretroviral treatment in adults with HIV/AIDS. *International Journal of Medical Informatics* 2016;92:54–61.
3. Irizarry T, Dabbs AD, Curran CR. Patient portals and patient engagement: a state of the science review. *Journal of Medical Internet Research* 2015 Jun;17(6):15.
4. Zapata LB, Tregear SJ, Tiller M, Pazol K, Mautone-Smith N, Gavin LE. Impact of reminder systems in clinical settings to improve family planning outcomes: a systematic review. *American Journal of Preventive Medicine* 2015 Aug;49(2 Suppl. 1):s57–s64.
5. Manias E, Kinney S, Cranswick N, Williams A, Borrott N. Interventions to reduce medication errors in pediatric intensive care. *Annals of Pharmacotherapy* 2014 Oct;48(10):1313–31.
6. Georgiou A, Prgomet M, Paoloni R, Creswick N, Hordern A, Walter S, et al. The effect of computerized provider order entry systems on clinical care and work processes in emergency departments: a systematic review of the quantitative literature. *Annals of Emergency Medicine* 2013 Jun;61(6):644–53.
7. Kruse CS, Goetz K. Summary and frequency of barriers to adoption of CPOE in the US. *Journal of Medical Systems* 2015 Feb;39(2):15.
8. Delvaux N, Van Thienen K, Heselmans A, de Velde SV, Ramaekers D, Aertgeerts B. The effects of computerized clinical decision support systems on laboratory test ordering: a systematic review. *Archives of Pathology and Laboratory Medicine* 2017 Apr;141(4):585–95.
9. Cleveringa FG, Gorter KJ, van den Donk M, van Gijzel J, Rutten GE. Computerized decision support systems in primary care for type 2 diabetes patients only improve patients' outcomes when combined with feedback on performance and case management: a systematic review. *Diabetes Technology and Therapeutics* 2013 Feb;15(2):180–92.
10. Ali SM, Giordano R, Lakhani S, Walker DM. A review of randomized controlled trials of medical record powered clinical decision support system to improve quality of diabetes care. *International Journal of Medical Informatics* 2016 Mar;87:91–100.
11. Hibbs SP, Nielsen ND, Brunskill S, Doree C, Yazer MH, Kaufman RM, et al. The impact of electronic decision support on transfusion practice: a systematic review. *Transfusion Medicine Reviews* 2015 Jan;29(1):14–23.
12. Baysari MT, Lehnbohm EC, Li L, Hargreaves A, Day RO, Westbrook JI. The effectiveness of information technology to improve antimicrobial prescribing in hospitals: a systematic review and meta-analysis. *International Journal of Medical*

- Informatics 2016 Aug;92:15–34.
13. Kruse CS, Bolton K, Freriks G. The effect of patient portals on quality outcomes and its implications to meaningful use: a systematic review. *Journal of Medical Internet Research* 2015 Feb;17(2):70–7.
  14. Otte-Trojel T, de Bont A, Rundall TG, van de Klundert J. How outcomes are achieved through patient portals: a realist review. *Journal of the American Medical Informatics Association* 2014;21(4):751–7.
  15. Goldzweig CL, Orshansky G, Paige NM, Towfigh AA, Haggstrom DA, Miake-Lye I, et al. Electronic patient portals: evidence on health outcomes, satisfaction, efficiency, and attitudes. *Annals of Internal Medicine* 2013 Nov;159(10):677–87.
  16. Ranji SR, Rennke S, Wachter RM. Computerised provider order entry combined with clinical decision support systems to improve medication safety: a narrative review. *BMJ Quality and Safety* 2014 Sep;23(9):773–80.
  17. 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 Nov–Dec;14(6):325–37.
  18. Cahill JE, Gilbert MR, Armstrong TS. Personal health records as portal to the electronic medical record. *Journal of Neuro-Oncology* 2014 Mar;117(1):1–6.
  19. Amante DJ, Hogan TP, Pagoto SL, English TM. A systematic review of electronic portal usage among patients with diabetes. *Diabetes Technology and Therapeutics* 2014 Nov;16(11):784–93.
  20. Bush RA, Connelly CD, Fuller M, Perez A. Implementation of the integrated electronic patient portal in the pediatric population: a systematic review. *Telemedicine and e-Health* 2015 Aug 10.
  21. Boksmati N, Butler-Henderson K, Anderson K, Sahama T. The effectiveness of SMS reminders on appointment attendance: a meta-analysis. *Journal of Medical Systems* 2016;40(4):90.
  22. Burhenn PS, Smudde J. Using tools and technology to promote education and adherence to oral agents for cancer. *Clinical Journal of Oncology Nursing* 2015;19(3 Suppl):53–9.
  23. de Jongh T, Gurol-Urganci I, Vodopivec-Jamsek V, Car J, Atun R. Mobile phone messaging for facilitating self-management of long-term illnesses. *Cochrane Database of Systematic Reviews* 2012 (12).
  24. Desai M, Woodhall SC, Nardone A, Burns F, Mercey D, Gilson R. Active recall to increase HIV and STI testing: a systematic review. *Sexually Transmitted Infections* 2015;91(5):314–23.
  25. Finitsis DJ, Pellowski JA, Johnson BT. Text message intervention designs to promote adherence to antiretroviral therapy (ART): a meta-analysis of randomized controlled trials. *PloS One* 2014;9(2):e88166.
  26. Gurol-Urganci I, de Jongh T, Vodopivec-Jamsek V, Atun R, Car J. Mobile phone messaging reminders for attendance at healthcare appointments. *Cochrane Database of Systematic Reviews* 2013 (12).

27. Harrison S, Stadler M, Ismail K, Amiel S, Herrmann-Werner A. Are patients with diabetes mellitus satisfied with technologies used to assist with diabetes management and coping? A structured review. *Diabetes Technology and Therapeutics* 2014;16(11):771–83.
28. Holcomb LS. A taxonomic integrative review of short message service (SMS) methodology: a framework for improved diabetic outcomes. *Journal of Diabetes Science and Technology* 2015;9(6):1321–6.
29. Kannisto KA, Koivunen MH, Valimaki MA. Use of mobile phone text message reminders in health care services: a narrative literature review. *Journal of Medical Internet Research* 2014 Oct 17;16(10):e222.
30. Kauppi K, Välimäki M, Hätönen HM, Kuosmanen LM, Warwick-Smith K, Adams CE. Information and communication technology based prompting for treatment compliance for people with serious mental illness. *Cochrane Database of Systematic Reviews* 2014 (6).
31. Mistry N, Keepanasseril A, Wilczynski NL, Nieuwlaat R, Ravall M, Haynes RB, et al. Technology-mediated interventions for enhancing medication adherence. *Journal of the American Medical Informatics Association* 2015;22(e1):e177–e93.
32. Park LG, Howie-Esquivel J, Dracup K. A quantitative systematic review of the efficacy of mobile phone interventions to improve medication adherence. *Journal of Advanced Nursing* 2014;70(9):1932–53.
33. Poorman E, Gazmararian J, Parker RM, Yang B, Elon L. Use of text messaging for maternal and infant health: a systematic review of the literature. *Maternal and Child Health Journal* 2015;19(5):969–89.
34. Smith C, Gold J, Ngo TD, Sumpter C, Free C. Mobile phone-based interventions for improving contraception use. *Cochrane Database of Systematic Reviews* 2015 (6).
35. Spoelstra SL, Sansoucie H. Putting evidence into practice: evidence-based interventions for oral agents for cancer. *Clinical Journal of Oncology Nursing* 2015;19(3):60– 72.
36. Stubbs ND, Sanders S, Jones DB, Geraci SA, Stephenson PL. Methods to reduce outpatient non-attendance. *American Journal of the Medical Sciences* 2012;344(3):211–9.
37. Tao D, Xie L, Wang T, Wang T. A meta-analysis of the use of electronic reminders for patient adherence to medication in chronic disease care. *Journal of Telemedicine and Telecare* 2015;21(1):3–13.
38. Tran N, Coffman JM, Sumino K, Cabana MD. Patient reminder systems and asthma medication adherence: a systematic review. *Journal of Asthma* 2014 Jun;51(5):536–43.
39. Wald DS, Butt S, Bestwick JP. One-way versus two-way text messaging on improving medication adherence: meta-analysis of randomized trials. *American Journal of Medicine* 2015;128(10):1139.e1–e5.
40. Hesselink G, Schoonhoven L, Barach P, Spijker A, Gademan P, Kalkman C, et al. Improving patient handovers from hospital to primary care: a systematic review.

Annals of Internal Medicine 2012 Sep 18;157(6):417–28.

41. Kattel S, Manning DM, Erwin PJ, Wood H, Kashiwagi DT, Murad MH. Information transfer at hospital discharge: a systematic review. *Journal of Patient Safety* 2016 2016.
42. Unnewehr M, Schaaf B, Marev R, Fitch J, Friederichs H. Optimizing the quality of hospital discharge summaries: a systematic review and practical tools. *Postgraduate Medicine* 2015 Aug;127(6):630–9.
43. Chen Y, Brennan N, Magrabi F. Is email an effective method for hospital discharge communication? A randomized controlled trial to examine delivery of computer-generated discharge summaries by email, fax, post and patient hand delivery. *International Journal of Medical Informatics* 2010;79(3):167–72.
44. Afilalo M, Lang E, Léger R, Xue X, Colacone A, Soucy N, et al. Impact of a standardized communication system on continuity of care between family physicians and the emergency department. *Canadian Journal of Emergency Medicine* 2007;9(2):79–86.
45. Maslove DM, Leiter RE, Griesman J, Arnott C, Mourad O, Chow C-M, et al. Electronic versus dictated hospital discharge summaries: a randomized controlled trial. *Journal of General Internal Medicine* 2009;24(9):995–1001.
46. O'Leary KJ, Liebovitz DM, Feinglass J, Liss DT, Evans DB, Kulkarni N, et al. Creating a better discharge summary: improvement in quality and timeliness using an electronic discharge summary. *Journal of Hospital Medicine* 2009;4(4):219–25.
47. Reinke CE, Kelz RR, Baillie CA, Norris A, Schmidt S, Wingate N, et al. Timeliness and quality of surgical discharge summaries after the implementation of an electronic format. *American Journal of Surgery* 2014;207(1):7–16.
48. Harlan GA, Nkoy FL, Srivastava R, Lattin G, Wolfe D, Mundorff MB, et al. Improving transitions of care at hospital discharge – implications for pediatric hospitalists and primary care providers. *Journal for Healthcare Quality* 2010;32(5):51–60.
49. Abbas M, Ward T, Peivandi M, McKenzie E, Kujawska-Debiec K, Hills A. Quality of psychiatric discharge summaries: a service evaluation following the introduction of an electronic discharge summary system. *Irish Journal of Psychological Medicine* 2015;32(4):327–30.
50. Callen JL, Alderton M, McIntosh J. Evaluation of electronic discharge summaries: a comparison of documentation in electronic and handwritten discharge summaries. *International Journal of Medical Informatics* 2008;77(9):613–20.
51. Kirby J, Barker B, Fernando DJ, Jose M, Curtis C, Goodchild A, et al. A prospective case control study of the benefits of electronic discharge summaries. *Journal of Telemedicine and Telecare* 2006;12, suppl. 1:20–1.
52. Acheampong F, Anto BP, Koffuor GA. Medication safety strategies in hospitals – a systematic review. *The International Journal of Risk and Safety in Medicine* 2014;26(3):117– 31.
53. Brown CL, Mulcaster HL, Triffitt KL, Sittig DF, Ash JS, Reygate K, et al. A systematic review of the types and causes of prescribing errors generated from using

- computerized provider order entry systems in primary and secondary care. *Journal of the American Medical Informatics Association* 2017 Mar;24(2):432–40.
54. Cresswell K, Mozaffar H, Shah S, Sheikh A. Approaches to promoting the appropriate use of antibiotics through hospital electronic prescribing systems: a scoping review. *International Journal of Pharmacy Practice* 2017 Feb;25(1):5–17.
  55. Keers RN, Williams SD, Cooke J, Walsh T, Ashcroft DM. Impact of interventions designed to reduce medication administration errors in hospitals: a systematic review. *Drug Safety* 2014 May;37(5):317–32.
  56. Nuckols TK, Smith-Spangler C, Morton SC, Asch SM, Patel VM, Anderson LJ, et al. The effectiveness of computerized order entry at reducing preventable adverse drug events and medication errors in hospital settings: a systematic review and meta-analysis. *Systematic Reviews* 2014 Jun 04;3:56.
  57. Brenner SK, Kaushal R, Grinspan Z, Joyce C, Kim I, Allard RJ, et al. Effects of health information technology on patient outcomes: a systematic review. *Journal of the American Medical Informatics Association* 2016 Sep;23(5):1016–36.
  58. Prgomet M, Li L, Niazkhani Z, Georgiou A, Westbrook JI. Impact of commercial computerized provider order entry (CPOE) and clinical decision support systems (CDSSs) on medication errors, length of stay, and mortality in intensive care units: a systematic review and meta-analysis. *Journal of the American Medical Informatics Association* 2017 Mar;24(2):413–22.
  59. Manias E, Williams A, Liew D. Interventions to reduce medication errors in adult intensive care: a systematic review. *British Journal of Clinical Pharmacology* 2012 Sep;74(3):411–23.
  60. Keasberry J, Scott IA, Sullivan C, Staib A, Ashby R. Going digital: a narrative overview of the clinical and organisational impacts of e-health technologies in hospital practice. *Australian Health Review* 2017 Jan 09;41(6):646–64.
  61. Page N, Baysari MT, Westbrook JI. A systematic review of the effectiveness of interruptive medication prescribing alerts in hospital CPOE systems to change prescriber behavior and improve patient safety. *International Journal of Medical Informatics* 2017 Sep;105:22–30.
  62. Niazkhani Z, Pirnejad H, Rashidi Khazaei P. The impact of health information technology on organ transplant care: a systematic review. *International Journal of Medical Informatics* 2017 Apr;100:95–107.
  63. Gagnon MP, Nsangou ER, Payne-Gagnon J, Grenier S, Sicotte C. Barriers and facilitators to implementing electronic prescription: a systematic review of user groups' perceptions. *Journal of the American Medical Informatics Association* 2014 May–Jun;21(3):535–41.
  64. Jones SS, Rudin RS, Perry T, Shekelle PG. Health information technology: an updated systematic review with a focus on meaningful use. *Annals of Internal Medicine* 2014 Jan 07;160(1):48–54.
  65. Kukreti V, Cosby R, Cheung A, Lankshear S. Computerized prescriber order entry in the outpatient oncology setting: from evidence to meaningful use. *Current Oncology* 2014 Aug;21(4):e604–e12.

66. Melton BL. Systematic review of medical informatics-supported medication decision making. *Biomedical Informatics Insights* 2017 Mar;9:1–7.
67. Minshall S. A review of healthcare information system usability and safety. *Studies in Health Technology and Informatics* 2013;183:151–6.
68. Weir CR, Staggars N, Laukert T. Reviewing the impact of computerized provider order entry on clinical outcomes: the quality of systematic reviews. *International Journal of Medical Informatics* 2012 Apr;81(4):219–31.
69. Lainer M, Mann E, Sonnichsen A. Information technology interventions to improve medication safety in primary care: a systematic review. *International Journal for Quality in Health Care* 2013 Oct;25(5):590–8.
70. Matui P, Wyatt JC, Pinnock H, Sheikh A, McLean S. Computer decision support systems for asthma: a systematic review. *NPJ Primary Care Respiratory Medicine* 2014 May;24:14005.
71. Kuposov R, Fossum S, Frodl T, Nytro O, Leventhal B, Sourander A, et al. Clinical decision support systems in child and adolescent psychiatry: a systematic review. *European Child and Adolescent Psychiatry* 2017 Apr 28;26(11):1309–17.
72. Kilsdonk E, Peute LW, Jaspers MW. Factors influencing implementation success of guideline-based clinical decision support systems: a systematic review and gaps analysis. *International Journal of Medical Informatics* 2017 Feb;98:56–64.
73. Holstiege J, Mathes T, Pieper D. Effects of computer-aided clinical decision support systems in improving antibiotic prescribing by primary care providers: a systematic review. *Journal of the American Medical Informatics Association* 2015 Jan;22(1):236–42.
74. Nurek M, Kostopoulou O, Delaney BC, Esmail A. Reducing diagnostic errors in primary care. A systematic meta-review of computerized diagnostic decision support systems by the LINNEAUS collaboration on patient safety in primary care. *European Journal of General Practice* 2015;21(Suppl. 1):8–13.
75. Bennett P, Hardiker N. A quantitative study investigating the effects of computerised clinical decision support in the emergency department. In: Sermeus W, Procter PM, Weber P, editors. *Nursing informatics 2016 e-health for all: every level collaboration from project to realization*. Amsterdam: IOS Press; 2016:53–7.
76. Nirantharakumar K, Chen YF, Marshall T, Webber J, Coleman JJ. Clinical decision support systems in the care of inpatients with diabetes in non-critical care setting: systematic review. *Diabetic Medicine* 2012 Jun;29(6):698–708.
77. Goldstein SL. Automated/integrated real-time clinical decision support in acute kidney injury. *Current Opinion in Critical Care* 2015 Dec;21(6):485–9.
78. Kashani K. Computer decision support for acute kidney injury: current and future. *Current Opinion in Critical Care* 2016 Dec;22(6):520–6.
79. Fartoumi S, Emeriaud G, Roumeliotis N, Brossier D, Sawan M. Computerized decision support system for traumatic brain injury management. *Journal of Pediatric Intensive Care* 2016 Sep;5(3):101–7.
80. Trinanes Y, Atienza G, Louro-Gonzalez A, de-las-Heras-Linero E, Alvarez-Ariza M,

- Palao DJ. Development and impact of computerised decision support systems for clinical management of depression: a systematic review. *Revista de Psiquiatría y Salud Mental* 2015 Jul-Sep;8(3):157–66.
81. Adams ES, Longhurst CA. Clinical decision support for pediatric blood product prescriptions. *Journal of Pediatric Intensive Care* 2016 Sep;5(3):108–12.
  82. Lopez KD, Gephart SM, Raszewski R, Sousa V, Shehorn LE, Abraham J. Integrative review of clinical decision support for registered nurses in acute care settings. *Journal of the American Medical Informatics Association* 2017 Mar;24(2):441–50.
  83. Anchala R, Pinto MP, Shroufi A, Chowdhury R, Sanderson J, Johnson L, et al. The role of decision support system (DSS) in prevention of cardiovascular disease: a systematic review and meta-analysis. *Plos One* 2012 Oct;7(10):8.
  84. Oluoch T, Santas X, Kwaro D, Were M, Biondich P, Bailey C, et al. The effect of electronic medical record-based clinical decision support on HIV care in resource-constrained settings: a systematic review. *International Journal of Medical Informatics* 2012 Oct;81(10):e83–e92.
  85. Jia P, Zhang L, Chen J, Zhao P, Zhang M. The effects of clinical decision support systems on medication safety: an overview. *PLoS One* 2016;11(12):e0167683.
  86. Bright TJ, Wong A, Dhurjati R, Bristow E, Bastian L, Coeytaux RR, et al. Effect of clinical decision-support systems: a systematic review. *Annals of Internal Medicine* 2012 Jul;157(1):29–43.
  87. Pombo N, Araujo P, Viana J. Knowledge discovery in clinical decision support systems for pain management: a systematic review. *Artificial Intelligence in Medicine* 2014 Jan;60(1):1–11.
  88. NHS England. [The forward view into action: paper-free at the point of care – completing the Digital Maturity Self-assessment](#) (PDF 2.3MB). London: NHS England; 2015. (accessed October 2017).
  89. NHS England. [The forward view into action: paper-free at the point of care – guidance for developing local digital roadmaps](#) (PDF 857KB). London: NHS England; 2016. (accessed October 2017).
  90. National Quality Forum. [Identification and prioritization of health IT patient safety measures](#) (PDF 857KB). Washington, DC: NQF; 2016. (accessed 12 October, 2017).
  91. World Health Organization. [WHO evaluation practice handbook](#) (PDF 971KB). Geneva: WHO; 2013. (accessed October 2017)
  92. Roper RA, Anderson KM, Marsh CA, Flemming AC. Health IT-enabled quality measurement: perspectives, pathways, and practical guidance. Rockville, MD: Agency for Healthcare Research and Quality; 2013.
  93. Standards Association of Australia. *Digital hospitals handbook*. Sydney: SAI Global Limited; 2017.
  94. Reed P, Conrad DA, Hernandez SE, Watts C, Marcus-Smith M. Innovation in patient-centered care: lessons from a qualitative study of innovative health care organizations in Washington state. *BMC Family Practice* 2012 December 14;13(1):120.

95. Office of the National Coordinator. [What is a patient portal?](#) 2015 [updated 2 November 2015; cited 2017 20 September].
96. Australian Digital Health Agency. [Australia's national digital health strategy](#). Canberra: ADHA; 2017. (accessed October 2017)
97. Checchi KD, Huybrechts KF, Avorn J, Kesselheim AS. Electronic medication packaging devices and medication adherence: a systematic review. *Journal of the American Medical Association* 2014;312(12):1237–47.
98. Australian Commission on Safety and Quality in Health Care. Literature review: medication safety in Australia. Sydney: ACSQHC; 2013.
99. Couper K, Yeung J, Nicholson T, Quinn T, Lall R, Perkins GD. Mechanical chest compression devices at in-hospital cardiac arrest: a systematic review and meta-analysis. *Resuscitation* 2016 Jun;103:24–31.
100. Jones CD, Cumbler E, Honigman B, Burke RE, Boxer RS, Levy C, et al. Hospital to post-acute care facility transfers: identifying targets for information exchange quality improvement. *Journal of the American Medical Directors Association* 2017 Jan;18(1):70–3.
101. Kruse CS, DeShazo J, Kim F, Fulton L. Factors associated with adoption of health information technology: a conceptual model based on a systematic review. *JMIR Medical Informatics* 2014 May 23;2(1):e9.
102. Moja L, Kwag KH, Lytras T, Bertizzolo L, Brandt L, Pecoraro V, et al. Effectiveness of computerized decision support systems linked to electronic health records: a systematic review and meta-analysis. *American Journal of Public Health* 2014 Dec;104(12):e12–e22.
103. Anchala R, Di Angelantonio E, Prabhakaran D, Franco OH. Development and validation of a clinical and computerised decision support system for management of hypertension (DSS-HTN) at a primary health care (PHC) setting. *PLoS One* 2013;8(11):e79638.
104. Anchala R, Pant H, Prabhakaran D, Franco OH. Decision support system (DSS) for prevention of cardiovascular disease (CVD) among hypertensive (HTN) patients in Andhra Pradesh, India: a cluster randomised community intervention trial. *BMC Public Health* 2012 May;12:7.
105. Jeffery R, Iserman E, Haynes RB. Can computerized clinical decision support systems improve diabetes management? A systematic review and meta-analysis. *Diabetic Medicine* 2013 Jun;30(6):739–45.
106. Belard A, Buchman T, Forsberg J, Potter BK, Dente CJ, Kirk A, et al. Precision diagnosis: a view of the clinical decision support systems (CDSS) landscape through the lens of critical care. *Journal of Clinical Monitoring and Computing* 2017 Apr;31(2):261–71.
107. Kohn MS, Sun J, Knoop S, Shabo A, Carmeli B, Sow D, et al. IBM's health analytics and clinical decision support. *Yearbook of Medical Informatics* 2014 Aug 15;15(9):154–62.
108. Yusof MM, Kuljis J, Papazafeiropoulou A, Stergioulas LK. An evaluation framework

- for health information systems: human, organization and technology-fit factors (HOT-fit). *International Journal of Medical Informatics* 2008 30 June 2008;77(6):386–98.
109. Greenhalgh T, Shaw S, Wherton J. SCALS: a fourth-generation study of assisted living technologies in their organisational, social, political and policy context. *BMJ Open* 2016;6:e010208.
  110. Cresswell K, Sheikh A. Organizational issues in the implementation and adoption of health information technology innovations: an interpretative review. *International Journal of Medical Informatics* 2013;82(5):e73–e86.
  111. Tsiknakis M, Kouroubali A. Organizational factors affecting successful adoption of innovative e-health services: a case study employing the FITT framework. *International Journal of Medical Informatics* 2009;78(1):39–52.
  112. Gruber D, Cummings GG, Leblanc L, Smith DL. Factors influencing outcomes of clinical information systems implementation: a systematic review. *Computers, Informatics, Nursing* 2009;27(3):151–63.
  113. Murray E, Hekler EB, Andersson G, Collins LM, Doherty A, Hollis C, et al. Evaluating digital health interventions: key questions and approaches. *American Journal of Preventive Medicine* 2016;51(5):843–51.
  114. Ammenwerth E, Schnell-Inderst P, U. S. Vision and challenges of evidence-based health informatics: a case study of a CPOE meta-analysis. *International Journal of Medical Informatics* 2010;79(4):e83–e8.
  115. Machan C, Ammenwerth E, T. B. Publication bias in medical informatics evaluation research: is it an issue or not? *Studies in Health Technology and Informatics* 2006;124:957– 62.
  116. Ammenwerth E, Graber S, Herrmann G, Burkle T, J. K. Evaluation of health information systems – problems and challenges. *International Journal of Medical Informatics* 2003;71(2–3):125–35.
  117. Black A, Car J, Pagliari C, Anandan C, Cresswell K, Bokun T, et al. The impact of eHealth on the quality and safety of health care: a systematic overview. *PLoS Medicine* 2011;8(1):e1000387.
  118. World Health Organization. *Monitoring and evaluating digital health interventions: a practical guide to conducting research and assessment*. Geneva: WHO; 2016.
  119. Donabedian A. The quality of care. How can it be assessed? *Journal of the American Medical Association* 1988;260:1743–8.
  120. Agency for Healthcare Research and Quality. [Types of quality measures](#). Canberra: AHRQ; 2011 [cited 2017 13 October].
  121. Flott K, Callahan R, Darzi A, Mayer E. A patient-centered framework for evaluating digital maturity of health services: a systematic review. *Journal of Medical Internet Research* 2016;18(4):e75.
  122. Institute of Medicine. *Health IT and patient safety: building safer systems for better care*. Washington, DC: National Academies Press; 2012.
  123. Singh H, Sittig DF. Measuring and improving patient safety through health information

- technology: the Health IT Safety Framework. *BMJ Quality and Safety* 2016;25:226–32.
124. Øvretveit J. *Evaluating improvement and implementation for health*. New York: Open University Press; 2014.
  125. Velentgas P, Dreyer N, Nourjah P, Smith S, Torchia M, editors. *Developing a protocol for observational comparative effectiveness research: a user's guide*. Rockville, MD: Agency for Healthcare Research and Quality; 2013.
  126. Sittig D, Singh H. A new sociotechnical model for studying health information technology in complex adaptive healthcare systems. *Quality and Safety in Health Care* 2010;19(Suppl. 3):i68–i74.

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