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Quest for  
Quality and  
Improved  
Performance

# **Costs and benefits of health information technology: an updated systematic review**

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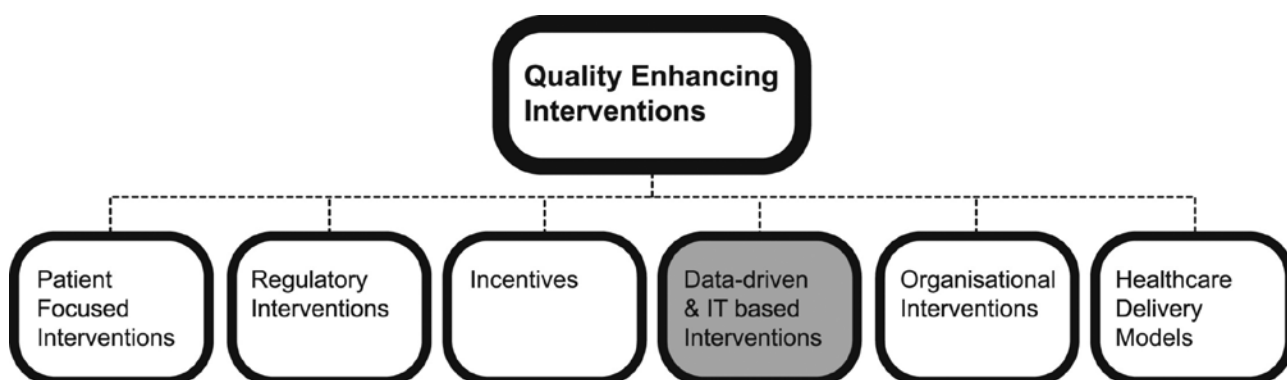
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# QQUIP and the Quality Enhancing Interventions project

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The Quality Enhancing Interventions component of the QQUIP initiative provides a series of structured evidence-based reviews of the effectiveness of a wide range of interventions designed to improve the quality of healthcare. The six main categories of Quality Enhancing Interventions for which evidence will be reviewed are shown below.



For more information visit [www.health.org.uk/quip](http://www.health.org.uk/quip)

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# Summary

## Introduction

The use of health information technology (HIT) has been promoted as having tremendous promise to improve the efficiency, cost-effectiveness, quality and safety of medical care delivery. The hope is that healthcare can follow the example of many non-healthcare industries – in which implementation of computer information technology has been a critical part of increasing the accessibility of information – and automate labour-intensive and inefficient processes, and minimise human error.

In 2005 we completed a systematic review of the costs and benefits of clinical HIT systems, commissioned by the United States Agency for Healthcare Research and Quality (AHRQ). This review also attempted to identify gaps in the literature in order to provide organisations, policy-makers, clinicians and consumers with an understanding of the effect of HIT on clinical care. The principal findings of the review were that a few organisations (referred to as the ‘HIT leaders’) have shown what can be achieved with the implementation of a multifunctional electronic health record (EHR) that includes computerised physician order entry (CPOE), decision support systems (DSS) and other functions. Since all the HIT leaders use systems that were locally developed over years with clinical champions, their experiences seem to offer little help for organisations seeking to implement, from scratch and in a more rapid fashion, multifunctional HIT systems purchased from vendors. We found scant published evidence to help guide interested organisations. Furthermore, we found little evidence at all regarding understanding the organisational context and process change that is seen as being critical to implementation of HIT. We concluded that ‘even if more randomized trials are performed, the generalizability of evidence would remain low unless more systematic, comprehensive, and relevant descriptions and measurements are made regarding how the technology is utilized, who are the individuals using it, and what is the environment in which it is used.’

In 2007 we embarked on an update of our review, commissioned by the Health Foundation.

## Methods

### What is generalisable knowledge regarding health information technology?

We use the term ‘generalisable knowledge’ to mean published evidence of the effects of a HIT intervention on costs and benefits that other healthcare organisations can use to implement HIT, and that they can reasonably expect will result in benefits similar to those reported in the original study. Therefore, generalisable knowledge from a study has two components: the internal validity of the study and the utility of the information for others considering implementing HIT. We focus here on the second component.

Organisational interventions interact with a wide range of system components. To be successful, they must address these organisational components in a locally effective way. Thus, these interventions are by nature not widely generalisable. This contrasts with studies of narrow interventions such as pharmaceuticals, which aim to identify treatment effectiveness that is generalisable across settings or providers. This difference has several important consequences. First, randomised controlled trials (RCTs) are not always feasible for assessing organisational change. Relying on randomised clinical trials only for evidence of the effect of HIT on costs and outcomes risks restricting the focus to narrow and tightly defined elements of HIT. In many real-world applications, complex organisational change interventions are implemented as a series of steps, with each step depending on the organisational

response to the previous step. Therefore, we judge that generalisable knowledge must and can come from many types of studies. However, we also assert that these studies must report details of the intervention and the organisational characteristics of where the intervention was implemented to allow other organisations to make judgements about the applicability of the results.

We consider the 'intervention' in HIT studies to have at least four components:

- technical: including the system components being tested (which may consist of CPOE, clinical charting or electronic prescribing), the pre-existing technology infrastructure (for example, clinical and financial systems, the network) and the existing electronic interfaces and integration
- human factors (machine–person interface): system usability (for example, 'user-friendliness', system response time, intuitive user interface, support for workflow processes) and support for specialty or context-specific actions (for example, clinical content, order-sets, and level and acceptability of clinical decision-support)
- project management: effecting complex socio-technical process change around HIT implementation, aligning IT and organisational resources to achieve project milestones and determining control of IT budgets
- organisational and cultural change, which may include a partnership of medical staff and administrative leadership to govern, align incentives and mobilise organisational inertia to achieve desired outcomes through process change.

Without an adequate description of all of these components in a study of HIT costs and benefits it is difficult for others to be able to infer how, or even whether, they can reproduce the results.

## Data sources and searches

We updated our original search, which ended in 2005, by performing a new monthly search from March to June 2007. The updated searches overlapped with the original search in order to ensure that we did not miss any studies. The databases we searched included PubMed (2004–2007), CINHALL (2003–2007), and Periodic Abstracts (2005–2007). We also searched the reference lists of each included study to identify any additional relevant studies.

## Study selection

Two independent reviewers (CG, AT) selected articles if they reported the effects of clinical HIT systems. Disagreements over content were resolved using consensus resolution. We did not assess non-clinical HIT systems, such as back-office billing and administrative systems, nor did we assess technologies such as robotics. Articles were classified as reviews, descriptive reports, hypothesis testing-studies and predictive analysis studies. We excluded non-systematic reviews and descriptive studies that did not include information on barriers to adoption or use.

## Data extraction

All studies were reviewed by at least two researchers. We used a standardised data abstraction form to determine key variables about each article. We resolved disagreements about article content and quality through discussion. Structured abstracts were developed by one investigator using a standard template and then data were checked by another investigator.

## Data synthesis

Based on considerations about a framework for considering costs and benefits of HIT and what constitutes generalisable knowledge, we determined that a synthesis of the results of the included studies could not be meaningfully accomplished using conventional AHRQ's Evidence-based Practice Center methods for such syntheses. In other words, because the interpretation of the results of HIT studies is quite context-specific, meta-analysis would not be appropriate. Instead, we created structured abstracts that can be used with our interactive database, which allows users to select the context most specific to their own needs and then rapidly find the relevant evidence.

From a broad policy perspective we identified and summarised evidence in five themes:

- the continuing results from the HIT leaders
- the evidence from commercial EHR systems
- the increase in HIT systems designed to be accessed directly by patients
- cost and cost–benefit/effectiveness
- barriers to adoption.

## Results

### Identifying the evidence

For this update we identified 4,683 titles in our library search and selected 180 articles; these contributed 183 studies for detailed review.

### Description of the evidence

Of the 183 studies included in the database, 22 pertained to decision support, 43 to electronic medical record and 43 to CPOE (categories are not mutually exclusive). There were 64 studies that assessed the effect of the HIT system in the outpatient or ambulatory setting while 71 examined its use in the hospital or inpatient setting. A randomised design was used by 46 studies, 7 were other controlled clinical trials, 35 used a pre–post design, 19 used a time-series design and another 27 were cross-sectional studies. The HIT systems at the Regenstrief Institute and Partners were each assessed in 4 and 12 separate studies, respectively: 6 studies assessed the US Department of Veterans Affairs (VA) health information system, 2 studied Intermountain Health, 8 studied Kaiser and 5 assessed the HIT system at Vanderbilt. We were able to identify only three studies that used a randomised or controlled clinical design, included cost data, and assessed HIT systems that were not located at one of the leading academic and institutional HIT institutions. All three tested standalone DSS that were not part of a multifunctional EHR. Among hypothesis-testing studies that used designs other than randomised controlled or clinically controlled trials and that did not come from the HIT leaders, only two reported cost data; neither of these assessed a multifunctional EHR. While we more readily found information about financial context, system sustainability and other implementation factors in this review than in our prior one, this information was only available in fewer than 10 per cent of studies.

### Theme 1: The HIT leaders continue to publish studies showing the potential benefits and limitations of multifunctional clinical HIT systems

In this review we identified 29 new studies from the HIT leaders. Taken together, these demonstrate both the potential and the limitations of improvements in care that may be realistically achieved in the near future with broader implementation of multifunctional EHRs. Improvements in the processes of

care and reductions in the number of preventable adverse drug reactions were reported in some, but not all, studies. Even with the use of HIT the standards of some processes of care remain far below what is desired (often less than half of eligible patients received recommended care despite the HIT intervention). Furthermore, problems abound with physicians ignoring or over-riding recommended care, suggesting a need for additional work on the acceptability of DSS and CPOE applications.

## **Theme 2: Although still rare in number, there are more published studies of commercial HIT systems**

In this update we identified publications reporting on multifunctional EHRs that have been developed commercially. While small in number, these papers represent an improvement over the near absence of such reports in our prior review. We found three kinds of studies of commercial HIT systems.

The first assessed the effect of adding new functionalities to existing HIT systems. These study results were similar to those reported by the HIT leaders: most demonstrated modest benefits, some found no benefits and a small number showed marked benefits. This supports the contention that the findings of studies from the HIT leaders about the effect of adding functionalities to existing EHRs is probably generalisable to other institutions.

The second type of study, of which there was only one, assessed the effects of the implementation of a HIT system on broader organisational measures. The authors, contrary to their expectations, found that implementing an EHR resulted in perceptions of a more hierarchical organisation. This supports the hypothesis that an organisation's culture and HIT implementation interact in complex ways.

The last kind of study we found was an assessment of the effect of introducing a multifunctional commercial EHR system into a healthcare setting where none had existed previously. This type of study is perhaps the most important for organisations considering purchasing an EHR, and we found only two.

## **Theme 3: There is a rise in the number of studies of HIT applications that are designed to be used by patients**

An emerging new theme in HIT is the rise of clinical applications that are designed to work apart from the multifunctional EHR. We identified 27 studies. The most interesting of these were studies of HIT applications designed to be accessed directly by patients, of which there were 18. These include Internet-based systems that are mostly self-help, 'e-health' systems that link patients with their care providers and are intended to improve the management of chronic diseases, and novel uses of existing technologies such as short message service (SMS) text messaging and personal digital assistants (PDAs) adapted to specific health purposes. The published evaluations of these interventions are mixed, with some showing no or only modest effects, and many more studies including insufficient information for us to reach conclusions on their effects.

## **Theme 4: Cost and cost-effectiveness data are still limited**

In this update we identified five cost-effectiveness or cost-benefit analyses of HIT. This was added to the five cost-benefit analyses regarding EHR implementation that we found in our original review. Our prior review concluded that five cost-benefit studies consistently predict that implementation of an EHR system can be financially viable for individual organisations or through a nationwide implementation with high levels of healthcare information exchange and interoperability. However, there are important caveats:

- all the studies are predictive analyses that are based on many analytical assumptions and limited empirical data



- the strength of the evidence is weak
- all the studies assumed that the EHR system had multiple functionalities that include, at a minimum, health information and data storage, administrative processes, DSS and results management, as well as information exchange capabilities
- the functional capability of an EHR system is critical to the benefits accrued
- both the cost and the benefit of attaining interoperability among EHR systems are directly proportional to the level of data exchange achieved.

Unfortunately, the updated review did not provide significant additional information regarding the costs and benefits of fully functional EHRs. Analyses of the costs and benefits of adding CPOE indicate that the results may be different depending on context. This reinforces the hypothesis that context is a critical component in considering the cost–benefit of clinical HIT systems.

### **Theme 5: There are still substantial barriers to implementation, and there has been modest progress on identifying or reporting on organisational factors crucial for adoption of HIT**

In our prior review we identified 20 publications that focused on the barriers to adopting and implementing HIT. Since then there has been modest progress on these issues: we identified proportionately more articles describing potential barriers – 46 articles in just over 2 years. Some of these were surveys of adoption rates or factors related to adoption. The primary barriers to adoption were cost and perceived resistance on the part of physicians. Recently, a case study of implementation was published that looked at the factors behind a successful implementation of an EHR, and compared these to expectations from Rogers' Theory of the Diffusion of Innovations and to prior literature. These factors included:

- consultation before implementation
- consensus about the need for a system and which one was best
- prioritisation and 'drive' from the management team
- competent IT project leader and team
- tested, user-friendly and intuitive system that could be used with little training
- potential for development of the system
- medication order entry not difficult to integrate after implementation (CPOE was not part of the initial implementation).

## **Discussion and conclusions**

We have found some encouraging developments since our prior review: there are more studies about the effects of commercial HIT systems and there is a bit more evidence about organisational context and factors associated with implementation. We also noted a new trend: the rise of HIT applications designed to be accessed directly by the patient. Most of these new applications have received insufficient evaluation for us to adequately judge their effects.

While predictive analyses, based on statistical modelling techniques, suggest that HIT has the potential to enable a dramatic transformation in the delivery of healthcare, the empirical research evidence base supporting HIT benefits is more limited.

Organisations that have realised major gains through the implementation of multifunctional, interoperable HIT systems built around an EHR include the US Department of Veterans Affairs, Partners, the Regenstrief Institute, Intermountain Health and Vanderbilt. In the past two years these institutions have continued to publish studies showing the benefits and limitations of multifunctional EHR systems. However, this update has revealed a modest increase in our knowledge about the factors associated with successful implementation and more widespread implementation of HIT is limited by the lack of generalisable knowledge about what types of HIT and methods of implementation will result in changes in benefits and costs for specific health organisations, especially for small practices and small hospitals. The specific context within which HIT is implemented – including the setting, the clinical issues and the patient populations – greatly influences its use and effects. The impact of HIT implementation on cost and quality will not be consistent across institutions, independent of context.

Even the most well-conducted studies of HIT interventions have results that fall disturbingly below expectations. Physician over-rides of alerts or lack of attention to DSS – often traced to problems with poor specificity of alerts and/or lack of physician time – show that without other organisational changes the gains from HIT, while noticeable, will not be transformational. It is clear that HIT is an enabler of transformation, probably even a necessary component, but not sufficient by itself.

From this review we can conclude that successful implementation of HIT systems likely requires the following actions:

- choose a system that is intuitive to use and that requires little training for users
- choose a system that can be modified and developed easily
- ensure that the decision-making process for developing or selecting a system is participatory, but once this decision has been taken ensure that implementation is directed and driven.

These findings need to be tested in other settings to understand the degree to which they are generalisable.

Implementation of HIT faces many barriers – principally these are cost and overcoming misgivings from physicians due to perceived adverse effects on their time. Improvements in the reporting of HIT developments and implementations can help to overcome these barriers. This includes providing more description of both the intervention and the organisational and economic environment in which it is implemented. In addition, a high priority must be placed on establishing standards for the information that needs to be measured and reported in HIT implementation studies, similar to the Consolidated Standards of Reporting Trials (CONSORT standards) for clinical trials of therapeutic interventions.

## Chapter 1. Introduction

The use of health information technology (HIT) has been promoted as having tremendous promise to improve the efficiency, cost-effectiveness, quality and safety of medical care delivery. The hope is that healthcare will follow the example of many non-healthcare industries – in which implementation of computer information technology has been a critical part of increasing the accessibility of information – and automate labour-intensive and inefficient processes, and minimise human error.

One of the most important uses for HIT may be to reduce medical errors. Technology-based strategies have proven to be effective in reducing the effects of human error in industries such as banking and aviation. Clinical HIT systems can make a substantial impact on medical quality and safety in a variety of ways. Having electronic access to complete patient health information can reduce treatment errors that result from gaps in knowledge regarding allergies, relevant medication and laboratory information, past medical history and poor communication among providers. HIT systems, such as automated decision-making and knowledge acquisition support tools, can integrate electronic patient information directly into the practices of medical providers in a seamless and complementary way. This can reduce errors of omission that result from gaps in provider knowledge or the failure to synthesise and apply that knowledge in clinical practice, and can result in more appropriate use of diagnostic tests and therapeutic agents.

In the ambulatory healthcare environment the use of HIT offers a variety of benefits. First, it can improve the efficiency and financial position of a practice. For years many offices have used computerised scheduling and financial systems to streamline office processes by tracking practice productivity and automating reimbursement processes. Second, the use of ambulatory electronic health records (EHRs) also offers an opportunity to monitor and improve clinical quality by improving access to information and reducing duplicate documentation. Technology-based ‘e-prescribing’ tools also may improve the efficiency and safety of prescribing practices in the outpatient setting in the same way as they have done in the hospital setting. Finally, the widespread adoption of HIT will create system connectivity and information exchange among providers of the same organisation, providers at different organisations and, ultimately, providers practising regionally and nationally.

However, the majority of medical organisations and providers in the USA have been slow to adopt HIT. Recent surveys of computerised physician order entry (CPOE) use show that only 9.6 per cent of hospitals have CPOE completely available for use, and only half of these hospitals require use of CPOE (Rood et al 2005). In the ambulatory setting, recent estimates suggest that only 6–15 per cent of office-based physicians use EHRs (Rosenbloom et al 2004; Madaras-Kelly 2006). The potential advantages of widespread adoption of HIT in a national healthcare system make it vital to examine the types of HIT systems being developed, the scientific evidence that currently supports the relative costs and benefits of HIT, and the barriers to implementing various types of HIT systems across the spectrum of healthcare environments.

In 2005, we completed a systematic review of the costs and benefits of clinical HIT systems, commissioned by the Agency for Healthcare Research and Quality (AHRQ). AHRQ asked us to review evidence on the costs and benefits associated with HIT and to identify gaps in the literature to provide organisations, policy-makers, clinicians and consumers with an understanding of the effect of HIT on clinical care. The principal findings of that review were that a few organisations (referred to as the ‘HIT leaders’) have shown what can be achieved with the implementation of a multifunctional EHR that includes CPOE, decision support systems (DSS) and other functions. Since all the HIT leaders use systems that were locally developed over a period of years with clinical champions their experiences seem to offer little help for organisations seeking to implement, from scratch and in a more rapid

fashion, multifunctional HIT systems purchased from vendors. We found scant published evidence to help guide interested organisations. Furthermore, we found little evidence regarding many of the things that are perceived to be crucial to understanding the organisational context and process change critical to implementation of HIT. We concluded that ‘even if more randomized trials are performed, the generalizability of evidence would remain low unless more systematic, comprehensive, and relevant descriptions and measurements are made regarding how the technology is utilized, the individuals who are using it, and the environment in which it is used.’

In 2007 we embarked on an update of our review, commissioned by the Health Foundation.

## A framework for considering the costs and benefits of health information technology

Organisations deciding whether to invest in HIT must weigh up the costs and benefits of doing so. Although the primary goal of non-profit healthcare organisations may be to provide high-quality care, they still need to manage their costs in order to survive. This includes understanding the costs of measures designed to improve quality. Such private return-on-investment (ROI) calculations can provide results that are quite different from those of societal cost–benefit analysis, which are often reported in clinical journals.

For example, one study showed that a hospital that installed a computerised reminder system to alert providers when patients were not up-to-date with their immunisations increased pneumococcal vaccine orders by 8 per cent (Bushnell et al 2006). Another study showed that, among older people, each US\$12 vaccination averts \$20.27 in hospital costs and increases life expectancy by an average of 1.2 days (Halamka et al 2006). From the point of view of the broader society, the reminder system saves money and improves health, so it is a win–win programme. However, from a financial perspective, the hospital has spent money on a system that had no effect on the costs or revenues of current stays because the pneumococcal vaccine is not provided in the hospital. To benefit from this intervention the hospital must develop a reputation for higher quality and convert it into higher revenue. This is one example of the potential for a mismatch between which organisation pays for HIT and which one accrues the cost savings arising from its use. A more extreme example would be a hospital’s implementation of a HIT intervention that averts future hospitalisation. In this case, HIT implementation both costs the hospital money and decreases hospital revenues, even if the HIT implementation has a net cost saving from a societal (or health service) perspective.

## Elements of the business case

The business case for investing in HIT must consider both financial and non-monetised consequences.<sup>1</sup> Any HIT investment has immediate costs with purchase, adaptation to an organisation and staff training. The business case for HIT therefore depends on the downstream financial benefits exceeding the immediate costs. Consider the following:

Profits = revenue – costs = (revenue per patient – costs per patient) × (number of patients)

With this equation in mind, long-term profits can come from increases in (profitable) patients, increases in revenues per patient or decreases in cost per patient. The easiest of these to understand is costs per patient. All organisations benefit from becoming more efficient and reducing the costs of providing

<sup>1</sup> Non-monetised consequences are costs and benefits that are not expressed in monetary terms. It may be easy to express some of them in a financial calculation, but difficult to realise the corresponding cash flows (for example, the time a person spends stuck in congestion might have a monetary value attached to it, but who would pay them?). It may be difficult to put a price on others.

particular services. HIT can reduce the waste involved in collecting information and getting it to where it is needed for better decision-making. This increase in efficiency can streamline healthcare and billing processes, and avoid the costs of unnecessary services and of dealing with errors, both in patient care and in billing. Also, working in high-quality organisations has some intangible benefits for staff, which may lead to better retention and productivity at equal levels of pay.

However, if HIT is used by an organisation to raise the quality of care or change the mix of services it provides, the resulting financial costs and benefits will depend on how the organisation is paid and what expenses it bears. These factors can greatly affect what kind of ROI is likely and when it will be realised. The next three paragraphs provide some examples.

A reputation for higher quality should increase the demand for an organisation's services in a competitive market, but it is difficult for an organisation to prove that it is better than its competitors or better than it used to be. HIT can both raise quality and generate the statistics to prove that an organisation has achieved this. Perceived higher quality may allow organisations to increase market share and to negotiate higher prices from payers whose members demand access to those organisations, even if they have to pay slightly higher premiums to get it. In a competitive fee-for-service environment, greater market share increases revenues and may also permit some economies of scale.

HIT can also be used to increase reimbursable services per patient, such as covered immunisations. HIT pays if it reduces waste, but it lessens profit if it reduces current or downstream services. Hospitals whose payments are set by a fixed payment that depends on the diagnosis of the patient but does not vary with actual costs will benefit from shorter lengths of stay (although the last days of a hospitalisation are the cheapest), but not (in general) from reduced readmissions. A hospital also will not benefit financially from interventions that shift care to physicians' practices.

The biggest gains from quality and HIT come when providers are paid by means of a capitated fee system. Under such a system, any investment that reduces the total costs of care for these patients can be recouped. It therefore pays to reduce unnecessary services and to provide care in the most efficient setting. HIT may help to share the information needed to do so. Such reasoning was behind the US Department of Veterans Affairs' (VA's) decision to develop its HIT system. Most published examples of cost-saving quality projects come from health maintenance organisations (HMOs) – for example, better diabetes or heart failure care that keeps patients out of hospital. Also for HMOs, high quality can offset other undesirable features – such as poor access or amenities – or can justify higher premiums. The gains to HMOs of better care will be more certain when capitation payments are adequately risk-adjusted. Without risk adjustment, providing high-quality chronic illness care – an area where HIT is particularly useful – may have the unprofitable side effect of attracting more-expensive patients.

Because some of the financial gains from high quality may go to purchasers (employers) rather than providers, particularly in non-capitated, fee-for-service environments, some purchasers have started to pay directly for quality. If the case for HIT were strong enough, insurers might want to subsidise it in part (that is, based on the insurer's share of the provider's caseload). However, unless an insurer covers most of the patients in a particular healthcare organisation or insurers agree to collaborate, it does not pay one insurer to subsidise HIT for an entire provider or organisation because a substantial portion of the cost savings accrue to other payers (the 'free rider' problem).

Non-healthcare businesses that are selecting investments might consider only financial ROI, but providing healthcare is a business with an unusual emphasis on non-monetised goals. The non-monetised part of the business case includes all non-monetary arguments that the organisation feels will influence the decision to adopt or reject the intervention. Examples include the following:

- maintaining credentials
- satisfying reporting requirements
- satisfying a requirement to do a quality improvement project
- avoiding exposure to liability
- building goodwill or reputation
- believing that it is ‘the right thing to do’.

Many of these non-monetised items have financial aspects. For example, the intervention may reduce the cost of meeting a pre-existing reporting requirement. Also, many organisations, particularly non-profit ones, have non-financial goals – such as providing high-quality care – in addition to financial goals.<sup>2</sup>

## What is generalisable knowledge regarding health information technology?

In this report we use the term ‘generalisable knowledge’ to mean published evidence of the effects of a HIT intervention on costs and benefits that other healthcare organisations can use to implement HIT, and that they can reasonably expect will result in benefits similar to those reported in the original study. Therefore, generalisable knowledge from a study has two components: the internal validity of the study and the utility of the information for others considering implementing HIT.

We can illustrate differences in generalisable knowledge by considering some examples. The simplest example is a particular pharmaceutical therapy for patients with a certain condition. In this case, a randomised placebo-controlled trial of the new pharmaceutical agent would be a study with good internal validity. Because pharmaceuticals are manufactured for consistency in strength and are given according to specified dosing schedules, another healthcare organisation examining the results of such a study could reasonably assume that administering the new pharmaceutical in the same doses and to patients with similar characteristics would result in benefits similar to those reported in the original study.

A second example would be the assessment of a new surgical therapy. Data may come from studies comparing patients randomly assigned to surgical therapy, from an alternate therapy, from non-randomised studies comparing surgically treated patients with historical controls or even from case series. As the confidence in the equivalence of the comparison groups at baseline diminishes, the difference in benefit must become greater for the reader to conclude that beneficial effects on outcomes are due to differences in therapy rather than other differences between groups at baseline.

Even after accepting that a particular study reports a real difference in outcomes between groups, the healthcare organisation or practitioner that is contemplating offering surgery must consider more factors than when considering the prescription of a new pharmaceutical agent. Surgical therapies are not as standardised as pharmaceutical agents, and outcomes depend on factors such as the skill of the surgical team and hospital. There is no reason to expect that every surgeon and hospital delivers equivalent care in the way that physicians and patients can expect a standard dose of a pharmaceutical to have the same potency. Hence, a study describing the effects of a surgical therapy needs to give more detail than a study describing the effects of a pharmaceutical drug. This includes enough of a description of the surgeon and hospital so that other healthcare organisations or providers can determine whether the reported outcomes are likely to be achieved in their own clinical situation.

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<sup>2</sup> Non-profit organisations may explicitly have commitments to provide the highest quality care, but for-profits also share medical ethics and culture to do the best they can for their patients.

When considering HIT evaluation, the situation becomes even more complex. Both the intervention and the subjects of the intervention are qualitatively different than in a study of a pharmaceutical or surgical intervention. HIT implementation consists of a complex organisational change undertaken to promote quality and efficiency. Studies of organisational change are fundamentally different from studies of medical therapies.

Organisational interventions interact with a wide range of system components. To be successful, they must address these organisational components in a locally effective way. Thus, these interventions are by nature not widely generalisable. This contrasts with studies of narrow interventions such as pharmaceuticals, which aim to identify treatment effectiveness that is generalisable across settings or providers. This difference has several important consequences. First, randomised controlled trials (RCTs) are not always feasible for assessing organisational change. Relying on randomised clinical trials only for evidence of the effect of HIT on costs and outcomes risks restricting the focus to narrow and tightly defined elements of HIT. In many real-world applications, complex organisational change interventions are implemented as a series of steps, with each step depending on the organisational response to the previous step. Therefore, we judge that generalisable knowledge must and can come from many types of studies. However, we also assert that these studies must report details of the intervention and the organisational characteristics of where the intervention was implemented to allow other organisations to make judgements about the applicability of the results.

We consider the ‘intervention’ in HIT studies to have at least four components:

- technical: including the system components being tested (which may consist of CPOE, clinical charting or electronic prescribing), the pre-existing technology infrastructure (for example, clinical and financial systems, the network) and the existing electronic interfaces and integration
- human factors (machine–person interface): system usability (for example, ‘user-friendliness’, system response time, intuitive user interface, support for workflow processes) and support for specialty or context-specific actions (for example, clinical content, order-sets, and level and acceptability of clinical decision-support)
- project management: effecting complex socio-technical process change around HIT implementation, aligning IT and organisational resources to achieve project milestones and determining control of IT budgets
- organisational and cultural change, which may include a partnership of medical staff and administrative leadership to govern, align incentives and mobilise organisational inertia to achieve desired outcomes through process change.

Without an adequate description of all of these components in a study of HIT costs and benefits it is difficult for others to be able to infer how, or even whether, they can reproduce the results.

Similarly, the analogue of the patient in a study of HIT is the ‘organisation’. No consensus exists regarding what aspects of the organisation are most important to report, but some are clearly vital. These include size, staffing, the organisation’s prior experience with quality improvement initiatives, processes expected to be influenced by the intervention and how these work currently, and the financial context of the organisation. These characteristics may well determine which types of HIT interventions work in a given setting. For this review we assessed whether studies measured some key organisational characteristics and what those characteristics were. These might be considered to be key ‘organisational demographics’, just as gender, age and severity of illness would be seen as the key demographic characteristics of a patient.

However, knowing these characteristics may not be enough to understand why a HIT intervention did or did not work. An organisation has to do more than simply buy the software to be successful. It must also invest in adapting the software to the organisation, developing new policies and procedures, and training staff. The extent to which the organisation is willing and prepared to perform these and other critical additional functions to embed the HIT into all relevant systems determines an organisation's readiness for change. Unfortunately, there is little scientific knowledge about which organisational characteristics are essential and which are unimportant. Thus, even if the description of a successful intervention includes many of the details described above, without information about organisational readiness, readers cannot know whether or not the same intervention is likely to work in their own organisation and how long and expensive the transitional process might be.



## Chapter 2. Methods

The Health Foundation requested an update of our AHRQ-supported evidence report on the costs and benefits of HIT systems. The purpose was to update the evidence base regarding the value of clinical HIT systems, in particular, the EHR and functionalities designed to work with it.<sup>3</sup>

### Literature search

Our original report started with an existing search that was conducted by a RAND Corporation project team, and also included an electronic search of PubMed on 6 January 2004 for reports of original research about HIT published since 1995; this search was later updated to 2005. We reviewed all articles on the HIT topics, regardless of study design or language (see Appendix A for specific search strategies). We also searched the Cochrane Controlled Clinical Trials Register Database and the Cochrane Database of Reviews of Effectiveness (DARE).<sup>4</sup>

For this update we performed a new monthly search from March to June 2007. The updated searches overlapped with the original search in order to ensure that we did not miss any studies. The databases we searched included PubMed (2004–2007), CINAHL (2003–2007), and Periodic Abstracts (2005–2007). As part of our usual methods we also searched the reference lists of each included study to identify any additional relevant studies.

### Article review

We reviewed the articles retrieved from the various sources against our exclusion criteria to determine whether to include them in the evidence synthesis and in the special interactive database we created to accompany this report (see below). We created a screening review form that contains a series of categorisation questions to track the articles (see Appendix B). Two reviewers, each trained in the critical analysis of scientific literature, independently reviewed each study, and resolved disagreements by consensus. The principal investigator resolved any disagreements that remained unresolved after discussions between the reviewers.

Our initial search was unrestricted by study design. The resulting articles were divided into four categories: reviews, descriptive reports, hypothesis testing-studies and predictive analysis studies.

### Reviews

Review articles identified by the search were classified as either systematic (including meta-analyses) or non-systematic. This determination was made by reading the methods section of the article to see whether an acceptable method was employed to identify evidence. This assessment was made by the research directors. Only systematic reviews were considered for further inclusion.

### Descriptive reports

Articles were classified as descriptive if they primarily described the workings or implementation of a HIT system. We further classified these as qualitative or quantitative based on the presentation of information regarding factors such as the number of tests ordered and costs of implementation. For this update, descriptive articles were not assessed further unless they included information on barriers to HIT adoption or use.

<sup>3</sup> The Health Foundation used two anonymous reviewers to provide critical comments on an earlier draft of this report.

<sup>4</sup> The Cochrane Collaboration is an international organisation that helps people make well-informed decisions about healthcare by preparing, maintaining and promoting the accessibility of systematic reviews on the effects of healthcare interventions.

### ***Hypothesis-testing studies***

This describes studies where the researchers attempted to answer a study question by comparing data between groups or across time periods and using statistical tests to assess differences. Hypothesis-testing studies were further classified into two groups. The first contained an intervention with a concurrent comparison group, which included randomised and non-randomised controlled trials and controlled before–after studies. The second group included studies with an intervention but without a concurrent comparison group, which included pre–post studies, time-series studies with more than two measurement points, and studies that used a historical control group. Additional classifications of hypothesis-testing studies included those without an intervention, which were cross-sectional in nature, and ‘other’ hypothesis-testing studies.

### ***Predictive analyses***

These included studies that used modelling techniques to predict what might happen with a HIT implementation rather than what did happen. Predictive analyses include cost-effectiveness and cost-benefit analyses. They typically use data from multiple studies and depend on several assumptions, some of which are not always stated explicitly.

## **Selecting articles and data elements for the interactive database**

We reviewed in more detail articles that were classified as systematic reviews, meta-analyses, hypothesis-testing or predictive analyses. For reasons discussed below, we created structured abstracts for these articles and placed them in an interactive database of HIT studies, which is available at <http://healthit.ahrq.gov/tools/rand>

We looked for the following data in each article:

- purpose of the study
- healthcare conditions that were studied
- year or years the study was performed
- study design
- outcomes reported, especially those related to changes in healthcare utilisation, quality of care and patient safety, healthcare costs, efficiency and productivity, revenue and time needed to accrue any benefits
- description of the study settings
- intervention and control arm
- evaluation method
- description of the HIT system, including how the system was acquired, the year the system was installed, the capability and comprehensiveness of the system
- integration of guidelines or decision support
- interoperability
- HIT implementation strategy
- financial context, such as whether it was a managed care or capitation environment, pay for performance, or area of public accountability
- system penetration

- facilitators and barriers
- evidence of the HIT system sustainability
- extrinsic factors in valuing costs and benefits
- cost of the HIT system or systems, including initial costs of the hardware and the software
- cost of implementation, including planning, hiring, training, temporary productivity loss, data entry, and other organisational resources
- long-term cost issues.

These data were judged to be important – and, in some cases, vital – to understand whether the study's results could contribute to generalisable knowledge.

## Synthesising the results

Based on considerations about a framework for considering costs and benefits of HIT and what constitutes generalisable knowledge, we determined that a synthesis of the results of the included studies could not be meaningfully accomplished using conventional methods from AHRQ's Evidence-based Practice Centers. In other words, because the interpretation of the results of HIT studies is quite context-specific, meta-analysis would not be appropriate. No studies were homogeneous or similar enough for us to be able to consider them together.

Similarly, a narrative review needs an organising construct, such as 'studies about CPOE', or 'studies of HIT in rural hospitals', or even 'studies of HIT that incorporate decision support and report benefits and costs for patient safety in the capitated ambulatory environment'. However, the possible combinations of key variables is so vast that any limited number of narrative syntheses we might produce for this evidence report inevitably would not meet the needs of many potential users. Therefore, we decided that the most useful synthesis of this evidence would be in the form of structured abstracts of the included studies, presented in the interactive searchable database, which can be used by interested readers to identify those HIT studies that meet their own particular contextual requirements.

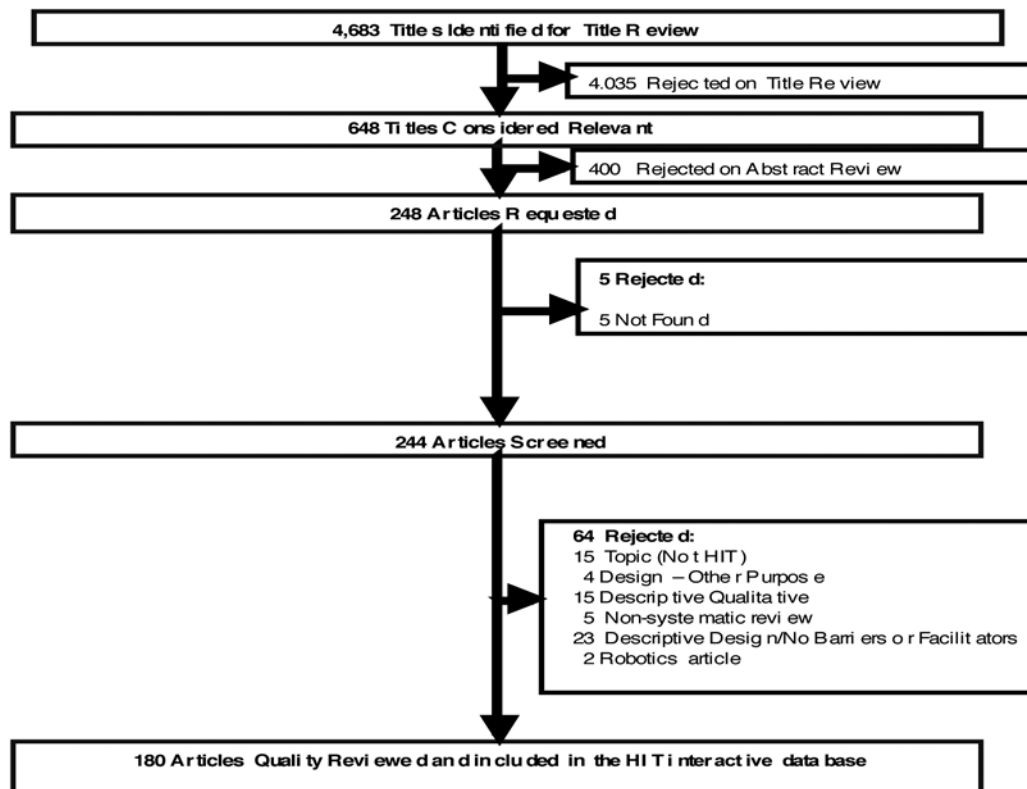
In addition to this, we present syntheses of information in several 'themes' that are new or related to the findings of our original review. We have structured these themes mostly from the perspective of policy-makers (see Chapter 3):

- Theme 1: The HIT leaders continue to publish studies showing the potential benefits and limitations of multifunctional clinical HIT systems.
- Theme 2: Although still rare in number, there are more published studies of commercial HIT systems.
- Theme 3: There is a rise in the number of studies of HIT applications designed to be used by patients.
- Theme 4: Cost and cost-effectiveness data are still limited.
- Theme 5: There has been some progress in understanding elements important for adoption of HIT, but much still remains to be done.

## Chapter 3. Results

We screened 244 articles and rejected 64: 15 did not have HIT as the subject, 5 were non-systematic reviews, 15 were descriptive qualitative studies, 4 had other ineligible designs, 23 were descriptive designs that did not report barriers or facilitators and 2 were robotics articles. We could not find five articles we were looking for. We included a total of 180 articles, representing 183 studies, in the HIT interactive database. Figure 1 presents this information pictorially.

**Figure 1. Health information technology (HIT) literature flow**



### Description of the studies

Of the 183 studies included in the database, 22 pertained to decision support, 43 to electronic medical record and 43 to CPOE (categories are not mutually exclusive). There were 64 studies that assessed the effect of the HIT system in the outpatient or ambulatory setting while 71 examined its use in the hospital or inpatient setting. A randomised design was used by 46 studies, 7 were other controlled clinical trials, 35 used a pre–post design, 19 used a time-series design and another 27 were cross-sectional studies.

Many of the studies concerned HIT systems developed and evaluated by academic and institutional leaders in HIT: the Regenstrief Institute, Partners/Brigham and Women’s Hospital, Intermountain Health, Kaiser, Vanderbilt and the US VA healthcare system. The HIT systems at the Regenstrief Institute and Partners were each assessed in 4 and 12 separate studies respectively: 6 assessed the VA health information system, 2 studied Intermountain Health, 8 studied Kaiser and 5 assessed the HIT system

at Vanderbilt. Studies from these institutions have contributed greatly to our knowledge about the usefulness of particular HIT functionalities (such as CPOE or computerised electronic alerts) and are examples of what can be realised by the implementation of broadly functional HIT at these specific institutions.

However, these studies have limitations in terms of their usefulness to inform decisions about the adoption of HIT in other locations. The primary concern is that (with the exception of Kaiser) these HIT systems were developed over the course of many years by champions at these institutions and, in a process of co-evolution, were specially adapted to the working environment and culture of their respective institutions. Consequently, the 'intervention' consists of not only the HIT system but also its local champions, who were often also the evaluators in published studies. Furthermore, it is challenging to calculate the cost of developing the HIT system as a whole, since this process has occurred over many years. Finally, these systems are not commercially available from vendors, whereas most HIT systems in the USA are commercial systems.

We were able to identify only three studies that used a randomised or controlled clinical design, included cost data and assessed HIT systems that were not located at one of the leading academic and institutional HIT institutions. All three tested standalone DSS and were not part of a multifunctional EHR. This means, as in our previous report, we were unable to find a single study that used a randomised or controlled clinical trial design, reported data from a site other than one of the leading academic or institutional HIT systems, reported cost outcomes and assessed a multifunctional HIT system. We fared little better by relaxing the requirement that the study be a controlled trial: among hypothesis-testing studies using designs other than a randomised controlled trial or clinically controlled trial and performed in a setting that wasn't one of the HIT leaders, only two reported cost data, and neither of these assessed a multifunctional EHR.

Regarding information about the organisational context of a HIT adoption and implementation, the literature is still sparse, although there has been some improvement compared with our report two years ago: 103 articles addressed at least one type of implementation factor. Almost 7 per cent of studies mentioned the financial context of the institution where the HIT intervention was implemented (financial context being a key factor in determining the ROI of implementing some kinds of HIT), up from less than 2 per cent at the time of our prior study. Regarding system penetration, about 2 per cent of studies in our prior review had this information; in the current review this is closer to 13 per cent. Eleven per cent of the studies report on facilitators to implementation and 25 per cent on barriers. Nearly 30 per cent described some form of implementation strategy. Cost data remain scant: only three studies discussed system costs, two implementation costs and three long-term costs. Importantly, only nine of the articles that included some information on implementation factors were describing multifunctional systems – that is, an EHR with at least one other component: CPOE or decision support system (DSS).

In summary, there has been little progress since our conclusion two years ago that 'we identified no study or collection of studies, outside of those from a handful of HIT leaders, that would allow a reader to make a determination about the generalisable knowledge of the system's reported benefit.' Besides the studies from HIT leaders, no other research assessed HIT systems with comprehensive functionality while also including data on costs, relevant information on organisational context and process change, and data on implementation. This limitation in generalisable knowledge is not simply a matter of study design and internal validity. Even if more RCTs are performed, the generalisability of evidence will remain low unless more systematic, comprehensive, and relevant descriptions and measurements are made regarding how the technology is utilised, the individuals using it and the environment it is used in.

As is apparent from the preceding discussion, the interpretation of studies of HIT is highly context-specific and is not amenable to the techniques of meta-analysis frequently used in other evidence reports to summarise results across studies. Certain functionalities of HIT systems have been the

subject of recent reviews, such as CPOE (Kaushal et al 2003), computer-based clinical DSS (Corley 2003; Garg et al 2005; Johnston et al 1994), and the use of computer-based guideline implementation systems (Shiffman et al 1999). We will not summarise these reviews here. Instead, we refer readers to the interactive database of HIT studies to select those that are most relevant to their own situation in terms of functionalities, clinical settings, outcomes reported and other factors.

## Major themes

The remainder of this chapter presents evidence in support of five major themes that we identified.

- Theme 1: The HIT leaders continue to publish studies showing the potential benefits and limitations of multifunctional clinical HIT systems.
- Theme 2: Although still rare in number, there are more published studies of commercial HIT systems.
- Theme 3: There is a rise in the number of studies of HIT applications designed to be used by patients.
- Theme 4: Cost and cost-effectiveness data are still limited.
- Theme 5: There has been some progress in understanding elements important for adoption of HIT systems, but much still remains to be done.

### **Theme 1: The HIT leaders continue to publish studies showing the potential benefits and limitations of multifunctional clinical HIT systems**

A theme in both our 2005 review and this update is that the HIT leaders continue to publish studies demonstrating the extent of the healthcare gains possible as well as the limitations of mature HIT systems. The HIT leaders were among the first to adopt health information technology, in particular, multifunctional EHRs. These organisations and healthcare systems now have more than 20 years of experience of using HIT. Partners Healthcare/Brigham and Women's Hospital, the Regenstrief Institute, Intermountain Health, Vanderbilt and the US Department of Veterans Affairs (VA) are the principal HIT leaders that publish studies.

In this update we identified 12 new studies from Partners/Brigham and Women's Hospital (Bu et al 2007; Dykes et al 2006; Gandhi et al 2005; Hsieh et al 2004; Judge et al 2006; Kaushal et al 2006; Maviglia et al 2007; Poon et al 2005, 2006; Rothschild et al 2007; Sequist 2005; Shah et al 2006). Two of the studies concerned bar code technology and are discussed in more detail in the next section (Maviglia et al 2007; Poon et al 2006). One study was a ROI assessment of CPOE and will be discussed in the cost section (Kaushal et al 2006). Three studies assessed the use of a DSS intervention in RCTs. The first study had the decision tool embedded into the CPOE component of the Brigham and Women's hospital EHR (Rothschild et al 2007). In this study, local experts created a set of guidelines for the transfusion of red blood cells, platelets and fresh frozen plasma, and then developed an educational programme for physicians that included pocket cards, lectures, newsletters and inclusion in Web-based reference materials. The investigators then created a pop-up screen that appeared whenever CPOE was used to order any of the targeted blood products. Clinicians were required to input certain clinical data; this information was assessed electronically to determine whether or not the clinical criteria met those specified by the guidelines. Accepted indications were processed, and rejected indications required a reason for rejection from a drop-down menu. When tested in a patient-level RCT, the DSS was associated with a modest but statistically significant improvement in ordering of about 4 per cent.

The two other DSS studies from Partners/Massachusetts General Hospital assessed ambulatory care. Electronic clinical reminders were developed for five processes of diabetes care (LDL cholesterol

testing, A1c testing, annual eye examinations, use of ACE inhibitors and use of statins) and four processes of coronary artery disease care (LDL cholesterol testing, aspirin therapy, beta-blocker therapy and statin therapy). Patient-specific reminders were delivered to physicians in the intervention group each time they opened the EHR for that patient (Sequist et al 2005). Compared with patients treated by control group physicians, intervention group physicians performed more cholesterol tests for diabetic patients and more frequently prescribed aspirin and statins for patients with coronary artery disease. Care for the other six process measures did not differ significantly between intervention and control groups. The second study assessed the use of a single patient-specific email sent to intervention physicians regarding patients in their practice who were above the target for LDL cholesterol, along with information about statin use (Lester et al 2006). Compared with control patients, a greater proportion of intervention patients had changes made to their statin prescriptions within one month (15 per cent versus 2 per cent) and there was a trend towards lower LDL levels, which was statistically significant in those patients whose baseline LDL was >130 mg/dl.

Another study from Partners/Brigham and Women's Hospital, in collaboration with the Center for Information Technology Leadership and others, modelled the effects of IT on diabetes management. It modelled US-wide implementation of systems to be used by providers (registries, report card summaries, decision support and so on), patients (self-management and remote monitoring), payers (comparison of care delivered with guidelines with feedback to providers), and an 'integrated diabetes management system' that would be a suite of technologies promoting more effective decisions (Bu et al 2007). The model projected an estimated savings of US\$14.5 billion for registries, \$10.7bn for decision support (the two most cost-saving technologies) and associated increases in processes of care such as increasing retinopathy screening rates from 14.2 to 61.5 per cent and increasing the foot examination rate from 45 to 80 per cent.

Four other studies looked at various aspects of CPOE: its use in the long-term care setting (Judge et al 2006), how many outpatient prescribing errors might be averted with sophisticated CPOE (Gandhi et al 2005), characteristics and consequences of drug allergy overrides (Hsieh et al 2004), and reasons for overrides (Shah et al 2006). Taken together, these studies indicate that:

- CPOE with dose and frequency checking has the potential to reduce adverse drug events
- overrides are common
- improvements in specificity of alerts might decrease the frequency of overrides
- tiering alerts results in greater acceptance of recommended actions.

The final study from Partners (Dykes et al 2006) was a survey of nurses, some of whom were affiliated with Partners, and some of whom were from different healthcare systems with IT systems in place, in order to understand the impact of IT on the role of nurses. The survey evaluated nurses' views regarding the ability of IT systems to facilitate communication, handovers, and interdisciplinary collaboration, among other areas.

We identified six studies from the VA (Agrawal and Mayo-Smith 2004; Arora et al 2005; McMahon et al 2005; Penz et al 2007; Rouf et al 2007; Roumie et al 2006). The VA operates the largest integrated healthcare system in the USA and its EHR is considered to be among the most sophisticated and mature. One study assessed the effect of a Web-based care management system for diabetes and will be discussed in the next section (McMahon et al 2005). Another assessed the effect of provider education, provider alerts and patient education on blood pressure control in a cluster randomised trial of 1,341 veterans cared for by 182 providers in 2 hospital-based and 8 community clinics (Roumie et al 2006). The alert was embedded in the VA's existing EHR, and consisted of a single patient-specific electronic notification sent by the pharmacy to the prescribing provider for each eligible patient during a

one-week period. The alert outlined current guidelines and reminded providers that a blood pressure of 140/90 mm Hg or less was the goal, summarised the patient's last 3 blood pressure readings (extracted from the EHR) and offered various options in terms of pharmaceutical management. The alert provided modest but statistically insignificant benefits over provider education alone, while the addition of patient education resulted in a statistically and clinically significant 17 per cent increase in the proportion of patients meeting the goal of a blood pressure of 140/90 or less. This study shows the importance of not relying solely on HIT to try to improve outcomes.

The second VA study looked at the adherence rate for 15 clinical reminders delivered to 451 clinicians in 49 clinics in 8 VA medical centres (Agrawal and Mayo-Smith 2004). The clinical reminders included ones for aspirin use and beta-blocker use after acute myocardial infarction, colorectal cancer screening, foot and eye examinations for diabetic patients, hepatitis screening, flu and pneumococcal vaccinations, mammograms, pap smears, tobacco use screening and cessation, and the preventive health review. During a 30-day period in 2003, there were 128,747 reminders reported as applicable and mean adherence by clinic was 86.2 per cent, which varied across clinics from 67 to 97 per cent.

The fourth VA study assessed a method of using natural language processing and word and phrase-matching algorithms to identify adverse events related to central venous catheters (Penz et al 2007). This technique used in an EHR could potentially replace the more time-consuming process of manual medical record review. This study compared manually-reviewed records with different computer-based methods. The authors report that a combination of both natural language processing and word and phrase-matching algorithms achieved a sensitivity of 72 per cent and a specificity of 81 per cent in identifying catheter-related adverse events. The authors conclude that significant potential exists for the use of such technologies for the identification of patients at-risk, adverse event surveillance and prevention via decision support.

The fifth VA study was a brief report of a new technology to automatically import vital signs directly from a patient's monitors into the VA's EHR – that is, no manual data input needed (Arora et al 2005). The time taken to record vital signs and nurse satisfaction were improved with the new system.

The final study evaluated whether physician experience affects the impact of examination room computers on the physician–patient interaction (Rouf et al 2007). Patients seeing physician trainees rather than attending physicians were more likely to believe that the computer adversely affected the time spent they spent with the physician and that the computer made the visit less personal. However, few patients felt that the computer interfered with their relationship with the physician.

We identified four studies from the University of Indiana/Regenstrief Institute (Dexter et al 2004; Laflamme et al 2005; Murray et al 2004; Tierney et al 2005). One study assessed the effect of computer-based standing orders compared with physician reminders for the delivery of influenza and pneumococcal vaccine to hospitalised patients; it used a randomised controlled design (Dexter et al 2004). For patients with standing orders, the EHR system automatically produced vaccine orders for eligible patients that were directed to nurses at the time of hospital discharge. Patients in the reminder group had their physicians receive computerised reminders that included suggested orders for vaccine delivery that could be accepted with one keystroke. During the 6 months of the study patients in the standing orders group received a statistically significant increase in both vaccines compared with patients in the physician reminder group (42 per cent versus 30 per cent of eligible patients for influenza vaccine; 51 per cent versus 31 per cent of eligible patients for pneumococcal vaccine).

Two studies from Regenstrief assessed the effect of computer-generated treatment suggestions displayed on physician or pharmacist workstations to improve the care of hypertension (Murray et al 2004) and asthma or chronic obstructive airway disease (Tierney et al 2005). Both studies were RCTs



using a factorial design for physician intervention, pharmacist intervention, both interventions or no intervention. There was no statistically significant difference favouring patients in any of the intervention groups compared with the control group.

The last study from Regenstrief assessed the effect of using electronic templates compared with standard dictation for the completion of operative reports. The use of templates resulted in an improvement in the time it took to complete a report and to comply with national standards, as well as avoiding transcription costs. However, it took a modestly longer period of physician time (6.77 minutes versus 5.96 minutes) (Laflamme et al 2005).

We identified five studies from Vanderbilt, all of which assessed CPOE or decision support within CPOE (Butler et al 2006; Hulgan et al 2004; Ozdas et al 2006; Potts et al 2004; Rosenbloom et al 2004). Three of the studies assessed care before and after the implementation of an intervention. In a study assessing implementation of CPOE in the paediatric critical care unit, potential adverse drug events fell from 2.2 per 100 orders before implementation to 1.3 per 100 orders after implementation, and reductions in medication prescribing errors and 'rule violations' (orders not compliant with hospital policies such as the use of abbreviations) were even greater (Potts et al 2004). The two other studies assessed care for patients with acute myocardial infarction and heart failure, and were before-and-after implementation studies. In one study the use of aspirin was increased by a statistically significant amount with the use of a standing order set for patients admitted with suspected acute myocardial infarction (Ozdas et al 2006). In the second study, the implementation of CPOE increased the use of smoking cessation counselling and discharge instructions for patients being discharged for acute myocardial infarction or heart failure, but there were no changes in the use of medications such as beta-blockers or ACE inhibitors (Butler et al 2006).

The two remaining studies from Vanderbilt related to decision support built into CPOE systems. The first was a time-series study evaluating the impact of computer prompts to providers to consider oral quinolones when they initiated an order for IV quinolones in patients who were potentially appropriate for oral therapy. The prompts resulted in an increase in the percentage of quinolone orders for the oral route on medical units but had no significant effect on surgical or intensive care units (Hulgan et al 2004). The second study was a survey of attitudes of physician trainees and medical students regarding the benefits of CPOE and integrated decision support or order sets. The majority of respondents had favourable views of CPOE's impact on efficiency and quality of care, but were not as supportive of the positive impact of integrated guidelines on care (Rosenbloom et al 2004).

We identified two new studies from Intermountain Health, another of the HIT leaders (Mosen et al 2004; Wilcox et al 2005). The first study assessed the impact of a computer-generated patient summary sheet that exists within their EHR (Wilcox et al 2005). The summary sheet can be printed and taken to a clinic visit, along with any other paper-based information, or accessed directly via a computer. In the 3 years after incorporation into the EHR, use of the summary sheet grew from 500 patients per month to more than 25,000 patients per month across the system of 472 physicians in 70 clinics. The authors reported that in some clinics it was used in about half of adult patient clinic visits, while in some clinics it was used rarely. Diabetic patient clinic visits where the worksheet was used had a statistically significant increase in overdue haemoglobin A1c testing from 68.4–76.7 per cent compared with patient visits where the worksheet was not used. The second study was a pre–post evaluation of the impact of a computerised clinical reminder designed to prevent post-operative deep venous thrombosis on rates of thromboembolic complications. While rates of prophylaxis increased by 5 per cent, there was no change in the rates of thromboembolic events (Mosen et al 2004).

## Summary

Taken together, these studies from the HIT leaders demonstrate both the potential and the limitations of improvements in care that may be realistically achieved in the near future with broader implementation of multifunctional EHRs. Improvements in the processes of care and reductions in the number of preventable adverse drug reactions were reported in some, but not all, studies. Even with the use of HIT, rates of some processes of care remain far below desired standards (for example, in the Regenstrief study of standing orders, even in the best performing groups only about half of eligible patients received recommended vaccinations) (Dexter et al 2004). Furthermore, problems with physicians ignoring or over-riding recommended care abound, suggesting a need for additional work on the acceptability of DSS and CPOE applications.

## Theme 2: Although still rare in number there are more published studies of commercial HIT systems

In this update we identified publications reporting on multifunctional EHRs that have been developed commercially. While still small in number, these papers represent an improvement over the near absence of such reports in our prior review.

Perhaps of greatest interest to providers and policy-makers are reports of the implementation of a commercially-available multifunctional EHR in settings that did not have an EHR. We identified two such studies (Garrido et al 2005; O'Neill and Klepack 2007). The first of these described the experience of two Kaiser-Permanente systems with similar but distinct EHRs (Garrido et al 2005). Kaiser in Colorado used a locally developed EHR (built in collaboration with IBM), and Kaiser Northwest used EpicCare. Both are multifunctional EHRs that include integrated documentation and reporting of results, CPOE and various kinds of decision support. Over an 8-year period of time (encompassing 4 years before and after implementation), the use of the EHR was associated with moderate and statistically significant decreases in patterns of ambulatory care use: about 8 per cent lower in year 4 compared to the pre-implementation baseline rate. During this same period telephone contacts increased from 1.26 per member per year to 2.09 per member per year at year 2 after implementation. Radiology service use decreased sharply at first (14 per cent) but then increased, although it remained 4 per cent lower than the time period prior to implementation. Similarly, laboratory use rates demonstrated a roughly similar pattern of decreases after implementation of the EHR. Three measures of process of care – advice on smoking cessation, cervical cancer screening and retinal examination in diabetic patients – remained unchanged or slightly improved after implementation.

The second such study assessed the effect of implementing a commercial EHR in a rural family practice in upstate New York (O'Neill and Klepack 2007). This case study described:

- the process for selecting a vendor for the EHR (which turned out to be Medant)
- the stages of EHR implementation (a phased process that required six months before all physicians were using the computer for progress notes, a little more than a year before electronic imaging ordering was added, two years before DSS for disease management were added and 2.5 years before all paper records were moved to storage)
- the impact on job responsibilities (need for physicians to assign ICD codes and for 'practice in preserving attentiveness and eye contact with the patient while simultaneously working with their [computers]')
- changes in nursing staff roles, front-desk staff roles and the office manager role (who became the in-house IT expert)
- the financial impact.

The authors report that average monthly revenue increased by 11 per cent in the first year and 20 per cent in the second year, and the charge–capture ratio increased by 65–70 per cent. All of this was due to better billing practices. Lastly, the authors report that three years after making the switch to the EHR ‘the practice was quite satisfied with the new system... While [it] had a positive financial impact, its main benefit was on supporting the core mission of providing care.’

One additional study assessed the effect of EHR use on various quality of care measures that are contained in the US National Ambulatory Medical Care Survey (Linder et al 2007). The use of EHRs was assessed by the answer to a survey question to providers that stated ‘does your practice use electronic medical records (not including billing records)?’. The answer was ‘yes’ for providers for 18 per cent of the patient visits. There was no consistent association between quality of care and respondents who answered ‘yes’.

We also identified a study that assessed the effect on organisational culture of converting to an EHR (Nowinski et al 2007). This study described the experience of a system-wide rollout of Epic Systems EHR at Northwestern Healthcare. The authors report that implementation occurred over a 17-month period and at the end of this time was used by all physicians, nurses and other personnel. Employees were surveyed using a culture and quality questionnaire, and patients were surveyed using the Press Ganey satisfaction instrument and various process and outcome measures such as haemoglobin A1c monitoring, prescription of ACE inhibitors and inpatient fall rates. Contrary to expectations, employees perceived the culture as becoming more, not less, hierarchical, and there were perceptions of modest decreases in group culture and leadership after EHR implementation. Patient satisfaction changed minimally and results on process and outcome measures were mixed: some rose and some fell with most changes not being statistically significant. The exceptions to this were decreases in the proportion of patients receiving antibiotics within 4 hours for suspected pneumonia and in the number of chest pain patients discharged within 23 hours.

Seven studies assessed the effect of CPOE when added to an existing EHR, or the addition of decision support to CPOE. These are less informative than studies assessing the implementation of an EHR where none previously existed. Two studies assessed the addition of the same commercial CPOE system being used in critically ill paediatric patients, with one study finding an unexpected increase in mortality following CPOE implementation (Han et al 2005) and the other failing to find any such increase (Del Beccaro et al 2006). The latter study’s authors postulate that one reason for their more favourable results was that they implemented their CPOE system later and learned from the earlier institution’s troubles.

Five studies assessed the effects of alerts and automated order sets in the context of commercial CPOE systems. The first study assessed the Kaiser Colorado system and tested in a randomised trial whether adding computerised reminders would increase the compliance with guidelines for laboratory monitoring at the initiation of therapy for a variety of medications including diuretics, ACE inhibitors, cholesterol-lowering drugs and diabetes medications (Palen et al 2006). Introducing alerts had no effect on appropriate monitoring, which occurred about 57 per cent of the time. The remaining studies were time-series evaluations of the effect of adding alerts or automated order sets. One study reported modest effects on some measures of medication ordering and laboratory test ordering with the use of alerts (Steele et al 2005). The second showed a decrease in the use of non-preferred drugs in older people after the institution of alerts (Smith et al 2006). A third study specifically assessed digoxin use and found increased use of digoxin and electrolyte monitoring with alerts (Galanter et al 2004). The last study in this group found that adding order sets to CPOE in the emergency department for patients with acute coronary syndrome did not result in increased use of beta-blockers, heparin or aspirin/clopidogrel (Asaro et al 2006).

We found two studies that assessed the addition of specific decision support to existing commercial HIT systems. The first was a randomised trial of a patient-specific reminder delivered as an email to primary care providers in their EHR 'in-folder' versus the same intervention plus a patient reminder mailed to the patient's address versus usual care for female patients at high risk for osteoporosis (Feldstein et al 2006). Patients in the EHR reminder group received statistically significantly more bone mineral density measurements at 6 months than patients in the usual care group (51.5 per cent versus 6 per cent); the addition of the patient reminder added nothing. The second study assessed the effect of patient-specific alerts for screening older Swedish patients for hypertension, anaemia, diabetes, hypothyroidism or vitamin B12 deficiency (Toth-Pal et al 2004). In this time-series study the proportion of patients tested rose dramatically after the introduction of reminders and exceeded 90 per cent for all 5 measures. The proportion of patients diagnosed with systolic hypertension or vitamin B12 deficiency was also statistically greater after alerts were introduced.

Lastly, we identified one study that assessed the stage of sophistication of the EHR system and performance on AHRQ quality measures at 107 academic health centres (Featherly et al 2007). These authors define seven stages of sophistication of IT implementation, with Stage 0 being no active electronic medical record technology, stage 1 being the use of IT for radiology, laboratory, and pharmacy, then adding functionalities so that by stage 4 the IT system includes decision support and physician order entry, ending with stage 7 being a fully automated in-house medical record integrated with patient's personal health records residing outside the institution. The authors' analysis concludes that with at least stage 4 adoption – the addition of CPOE and decision support/clinical protocols – health centres are more like to have better quality on 9 of the AHRQ quality measures.

### **Summary**

We found three kinds of studies of commercial HIT systems. The first assessed the effect of adding new functionalities to existing HIT systems. These study results were similar to those reported by the HIT leaders – most studies demonstrated modest benefits, some studies demonstrated no benefits and a small number of studies demonstrated marked benefits. This supports the contention that the findings of studies from the HIT leaders about the effect of adding functionalities to existing EHRs is probably generalisable to other institutions. The second type, of which there was only one, assessed the effects of the implementation of a HIT system on broader organisational measures. The authors, contrary to their expectations, found that implementing an EHR resulted in perceptions of a more hierarchical organisation. This supports the hypothesis that an organisation's culture and HIT implementation interact in complex ways. The third kind of study we found was an assessment of the effect of introducing a multifunctional commercial EHR system into a healthcare setting where none had existed previously. Although this last type of study is perhaps the most important for organisations considering purchasing an EHR, we only identified two examples.

### **Theme 3: There is a rise in the number of studies of HIT applications designed to be used by patients**

An emerging new theme in HIT is the rise of clinical applications designed to work apart from the multifunctional EHR. We identified 28 studies. Many of these new studies take existing concepts further, such as the use of computers to help assess diagnostic information. The computerised interpretation of the electrocardiogram is one such application that dates back at least 20 years. In that same vein, we identified studies that evaluated computer applications to aid the diagnosis of melanoma based on specialised pictures of skin lesions (Boldrick et al 2007) and the change in status of dental caries using specialised fluorescein-stained pictures of teeth (Pretty and Ellwood 2007). The field of telemedicine is also producing new research. One example is a study of telerehabilitation, where stroke patients wearing specialised motion sensors on their involved upper extremity were in computer contact with a remote therapist who was both monitoring the patient's arm motion and sending out a synchronised virtual environment scene that the patient was trying to imitate (Holden et al 2007). We also identified new

studies of various computerised or video decision aids to be used with patients and clinicians to promote shared decision-making regarding breast cancer prevention (Ozanne et al 2007), genetic testing for breast cancer susceptibility (Green et al 2004) and warfarin use for atrial fibrillation (Kaner et al 2007). We also identified some novel applications for specific purposes: for example, SMS text messaging to patients to remind them of an upcoming scheduled outpatient consultation (Downer et al 2006; Downer et al 2005) or of the need for vaccinations prior to international travel (Vilella et al 2004), and the use of bar codes and scanners for patients to fill in quality of life surveys (as opposed to using traditional pencil applications) (Boissy et al 2006).

In this section we will discuss in more detail studies of technologies designed to be used by patients in settings other than where doctors work (that is, applications that are not accessed in the doctor's office or waiting room, but could be accessed at home or elsewhere). While we did not collect data on this category in our prior review, the 18 studies we identified seemed to represent a significant increase.

Four of these studies involved Internet or Web-based applications that were accessed directly by the patient. They included topics as disparate as problem drinking (Cunningham et al 2006), advance care planning and healthcare proxy designation (Cintron et al 2006), weight control (Jacobi et al 2007) and complicated grief (Wagner et al 2006). Three studies were randomised trials (Cintron et al 2006; Jacobi et al 2007; Wagner et al 2006). In the first trial, patients already participating in an online system created at the Beth Israel Deaconess Medical Center that allowed patients to access their own medical records and to electronically communicate with their providers were randomised to receive either nothing additional or an electronic message that contained a hyperlink to the Massachusetts Medical Society's healthcare proxy website. Once there, patients could complete an online healthcare proxy form and also view an educational programme designed to help patients discuss healthcare proxies and end-of-life care preferences. Among the 430 persons randomised to receive the intervention, there was greater knowledge of what a healthcare proxy was and they were more likely to have a plan to complete one in the future. However, they were no more likely than the control group to have completed a healthcare proxy (four interventions, six control patients) (Cintron et al 2006). In the second trial, German researchers reported the successful translation and implementation of a US-developed Internet-based psychological intervention for young women at high risk of developing eating disorders (Jacobi et al 2007). The third trial assessed the effect of an Internet-enhanced cognitive behavioural therapy programme for patients with complicated grief (Wagner et al 2006). In this trial patients had two weekly writing assignments for a total of five weeks. Patients in the intervention group communicated with the psychologist and received feedback and further instructions exclusively via email. Compared with patients in a waiting list control, intervention patients had statistically significant improvements in a number of mental health measures included those related to anxiety, depression and adaptability.

The other Internet-based study was a pre–post analysis. The study was a preliminary report of the feasibility and three-month follow-up of a small number of patients who completed new modules regarding their drinking patterns as part of an online service called the Alcohol Help Center ([www.alcoholhelpcenter.net/](http://www.alcoholhelpcenter.net/)), which describes itself as 'an interactive cognitive behavioural therapy programme with a support group monitored by trained professionals'. The website contains a module called Check Your Drinking and the intervention was new questions designed to appeal to periodic heavy users. The study reported that subjects accessing this site found it useful, and at three months reported less drinking than at baseline. The authors caution about drawing inferences due to the potential for selection bias and attrition (Cunningham et al 2006). We note that there are a plethora of similar self-help sites although we found no published evidence assessing the effects of any of these.

Another study of a similar type of application (though not Internet-based), reported on the effects of a CD-ROM-based intervention to improve mother–daughter interactions in black urban adolescent girls (Schinke et al 2006). This CD-ROM had five intervention modules focused on building rapport as a foundation of positive communication, interpersonal relationships and respect between girls and their

mothers. Compared with 44 mother–daughter pairs who served as the control group, 42 pairs in the intervention group were found at 3-month follow-up to have non-statistically significant increases in girls reporting closeness and communication with their mothers. However, it did find small (and statistically significant) increases in mothers who reported closeness and communication with their daughters.

A third study was similarly designed to assess the effect of a HIT intervention for disadvantaged populations, in this case low-income women with a diagnosis of breast cancer (Gustafson et al 2005). This study assessed the effect of CHES, a home-based system described as providing information services including Web links, support services such as discussion groups and bulletin boards, and decision services including assessment, health charts and action plans. This evaluation enrolled a group of low-income women with a recent diagnosis of breast cancer or known metastatic disease. They were loaned a computer and given four months of Internet access. The authors report that these women logged on and used the system more than affluent women in a previous study, and that 95 per cent of participants used the system at least once and logged on just under 10 times in the first week.

Seven studies assessed the effects of an e-health system that links patients and doctors (Fung et al 2006; Glasgow et al 2005, 2006; Gustafson et al 2005; Harno et al 2006; McMahon et al 2005; Robertson et al 2006). These systems are included here since patients typically link to them from their own home, although they differ from the interventions described above in that they are also linked directly to the patient's usual source of care. One study describes the frequency of use of e-health systems by members of Kaiser Northern California (Fung et al 2006). This study reported that the proportion of members registered to use e-health rose from 0.7 per cent in 1999 to 8.6 per cent in 2002. Compared with non-users, members who used e-health were more likely to have a high level of clinical need (defined as membership in chronic disease registries for asthma, diabetes, heart failure and so on), to be aged between 30 and 64 years, female and white, and more likely not to live in a low socioeconomic neighbourhood.

Four studies assessed e-health systems for diabetes care. One brief report of such a system in Norway described a trial where patients were randomised to the e-health system or usual care. With this system, patients downloaded measurements from their blood glucose meter directly into a regional database using a modem; a 'self-management system allowed the diabetes team to transmit short message service text messages to patients with mobile phones and Internet access'. Data were shared across healthcare facilities in the region. At the end of 12 months the authors reported that HgbA1 levels fell from 8.21 to 7.83 in the control group and from 7.82 to 7.32 in the intervention group, a difference between groups that they said was statistically significant. Similarly, clinically very small differences between groups were described as statistically significant for diastolic blood pressure (2 mm Hg difference), cholesterol and triglycerides. There was one fewer clinic visit and one more telephone call during the 12-month period for intervention patients compared with control patients (Harno et al 2006). A second study, from the VA, was a trial of Web-based care management compared with usual care for patients with diabetes and an A1c value of 9 per cent or greater (McMahon et al 2005). Intervention patients received a notebook computer that was programmed to connect to a diabetes education and management website, which accepted uploads of blood pressure and glucose monitoring values. An advanced practice nurse reviewed data and used treatment algorithms to provide individualised recommendations to patients and primary care providers. Compared with control patients, intervention patients had a modestly greater but statistically significant decrease in A1c values at 12 months (decrease of -1.6 per cent versus -1.2 per cent,  $p < 0.05$ ). Similar-sized declines in systolic blood pressure were also found for the intervention patients. There was no difference between groups in LDL measurement changes.

Two other diabetes studies came from the same investigators. The first was a trial of a programme to assist patients and providers in the delivery of recommended laboratory screening, physical examination items and patient-centred items, as well as the development of a self-management plan (Glasgow et al

2005). Patients entered information using a touch screen computer that then generated three printouts: an action plan for the patient, a summary of the patient's required assessments and self-management goals for the provider, and a summary for the care manager. Compared with patients receiving usual care, patients in the intervention group had better completion rates for those processes of care that were low at baseline, much better completion rates for patient-centred activities such as self-management goal setting and medical nutrition management, but no differences in values for A1c, lipid control or quality of life. A second study from these investigators assessed the robustness of what was described as a very similar or identical intervention to the previous study (Glasgow et al 2006). This reported that the intervention achieved 41 per cent patient participation, was adopted in up to 76 per cent of healthcare settings (highest for HMOs, lower for non-HMOs) and improved behavioural outcomes but not clinical ones.

The last e-health study described use of a system to enhance depression care (Robertson et al 2006). This system provides patients with 12 online sessions over 12 months and includes tools such as cognitive behavioural therapy, psycho-education, a diary and automated patient-administered progress monitoring questionnaires. It also provides clinicians with online access to their patients' progress, and regular monitoring of patients by case managers to enable early detection of problems and clinician notification. The authors report that overall adherence to the system was high among 144 initial users (53 per cent adherence for patients receiving automated reminders and 84 per cent adherence for patients receiving case management) and that depression severity decreased, although this analysis was presented only for those patients who completed at least 8 sessions. The authors reported high patient and clinician satisfaction with the system.

We identified three studies that assessed a computerised cognitive behavioural therapy programme entitled *Beating the Blues* (Cavanagh et al 2006; Grime 2004; Proudfoot et al 2004). This is described as an interactive, multimedia, computerised, cognitive behavioural therapy package consisting of a 15-minute introductory videotape followed by 8 therapy sessions. Reports are generated for the patient and provider. In a randomised trial of adults with depression, mixed anxiety and depression, or anxiety disorder being seen in primary care (Proudfoot et al 2004) and another randomised trial conducted in an occupational health department for employees with 10 or more days of sickness absence for stress, anxiety or depression (Grime 2004), statistically significant improvements of modest size were found for patients in the intervention groups compared with usual care. (There was a three or four point difference on the Beck Depression Inventory, although in one study the statistically significant differences between groups had disappeared by three months and six months.) A third study of *Beating the Blues* assessed its use in primary care and secondary care in a pre–post fashion, with minimal research support. Although limited by a large dropout rate (only 18 per cent of patients completed a 6-month follow-up questionnaire) the researchers found an improvement of 0.50 in effect size for psychological measures (Cavanagh et al 2006).

We also identified two randomised trials of computer-assisted ways to improve subsequent patient–physician interaction. The first study compared a computer-assisted method for taking sexual history with a face-to-face method, and concluded that use of the computer resulted in the reporting of a significantly higher number of partners in the previous 12 months and a higher reporting of hepatitis B vaccination. The authors concluded the computer-assisted method is reliable, efficient, acceptable and could be used routinely (Tideman et al 2007). The second study assessed a computerised decision aid to help patients prepare for discussions with their doctor about cardiovascular risk reductions and reported that the decision aid increased the proportion of patients discussing CHD risk reduction from 16 to 40 per cent compared with no intervention, and increased the proportion of patients with a specific plan to reduce CHD risk (from 24 to 37 per cent) (Sheridan et al 2006).

Lastly, we identified a novel study of the use of a personal digital assistant (PDA) to assist women enrolled in the Diet Modification arm of the Women's Health Initiative (WHI) to better monitor their diet.

This self-described pilot study of 33 women reported that participants significantly increased their use of self-monitoring and met their dietary goals more often, compared with their prior use of hard copy. The authors posit that the PDA may represent a promising technique for improving dietary monitoring and adherence (Glanz et al 2006).

### **Summary**

There seems to be an increasing number of studies of HIT applications designed for patients. These include Internet-based systems that are mostly self-help, e-health systems that link patients with their care providers and are intended to improve the management of chronic diseases, and novel uses of existing technologies such as SMS text messaging and PDAs adapted to specific purposes for health. The published evaluations of these interventions are mixed, with some showing no, or only modest, effects, and many more studies described insufficiently to reach conclusions on their effects.

We note that this is a field where, particularly for the Internet-based self-help patient applications, there is far more innovation and implementation than there is evaluation. A simple Internet search of 'self help' combined with common chronic conditions (such as depression, diabetes, heart failure, panic disorder, fibromyalgia, back pain and so on) identified multiple websites for each condition; however, we did not identify evaluations of any of these Internet-based self-help sites. This is a burgeoning area for future research, both descriptive epidemiology (how many of these sites are there, how many people use them and so on), content analysis (how accurate is the information) and more formal evaluation studies.

### **Theme 4: Cost and cost-effectiveness data are still limited**

In this review, EHR refers to a HIT element that performs the functions of electronic recording, storage, accessing and viewing of patient medical information (Khoury 1997, 1998; Kian et al 1995; Wang et al 2003). An EHR system is a computer application that, at a minimum, has EHR functionality. Often, financial data are also included. Since the system is designed to be used institution-wide to replace paper-based medical records and to aid the efficiency of healthcare processes, many EHR applications also contain other system functions, including prescription and test ordering, care management reminders and other clinical decision support capabilities. While the EHR is considered essential technology for improving efficiency and quality of healthcare, implementation of an EHR system requires substantial capital investments and organisational change. Consequently, many healthcare organisations are seeking evidence and lessons learned about the costs and benefits of EHR adoption in order to better inform decisions about timing and strategies for implementing a system.

In this update and in our prior review we applied the criteria for assessing economic evaluation proposed by Drummond et al (2005) to assess the evidence on costs and cost-effectiveness. All selected articles for review met the article inclusion criteria for the study. In order to draw generalisable evidence and lessons, the most important criteria we used were:

- Was a comprehensive description of the competing alternatives given?
- Were all the important and relevant costs and consequences for each alternative identified?
- Were costs and consequences valued credibly?
- Did the presentation and discussion of study results include all issues of concern to users?

In our prior review, EHR was the second most common HIT element among the articles identified that contained economic data. Our prior literature search identified 92 hypothesis-testing or predictive analysis articles containing information on costs, utilisation or efficiency. Of these, 32 studies assessed a HIT system in which EHR was one of the major system elements. However, only nine articles quantitatively assessed the economic value of an EHR system as a whole. Most of the remaining studies



were tests of certain non-financial hypotheses or examinations of a subset of functionality, such as decision support, instead of the entire EHR system. Although these studies do not assess the costs and benefits of the entire system, they provide indirect, often empirical, evidence that can support the economic appraisal of the value of an EHR system. For instance, we reviewed studies that demonstrated the effectiveness and cost-effectiveness of HIT systems that facilitate automatic generation of patient reminders for preventive services, screening and disease management (McDowell et al 1986, 1989a, 1989b; Rosser et al 1991, 1992), studies that evaluated the benefits of electronic charting on provider productivity (Bulpitt et al 1976; Cameron et al 1999; Daly et al 2002; Krall 1995), and studies that demonstrated how HIT systems can improve patient safety and thereby prevent potential morbidity and its associated costs (Classen et al 1997; Evans et al 1992, 1993). Several studies investigated the impact of point-of-care alerts and reminders embedded within an EHR system during the process of documentation or entry of orders (Bates et al 1997; Jones et al 1996; McDonald 1976; Ornstein et al 1999; Tierney et al 1987, 1990, 1997; Wells et al 2003). These decision-support functions – when accompanied by the required changes in process and communication – altered physicians' ordering behaviours by facilitating appropriate resource utilisation and reducing unnecessary charges (Bates et al 1997; Jones et al 1996; McDonald 1976; Ornstein et al 1999; Tierney et al 1987, 1990, 1997; Wells et al 2003). Not all studies reviewed described positive effects on costs, and the benefits of information technology seem to depend greatly on the quality of the implementation and the level and type of decision-support technology.

Of the nine quantitative analyses identified in our prior review, five assessed the costs of implementing an EHR system (Arias-Vimarlund et al 1996; Khoury 1997, 1998; Kian et al 1995; Schmitt and Wofford 2002; Wang et al 2003), with the costs varying significantly by the scale of the healthcare organisation and the functionality of the EHR system. Our review found consistent predictions that implementation of an EHR system can be financially viable at the individual organisation level or through a nationwide implementation with high levels of healthcare information exchange and interoperability. However, there are several caveats. First, all of the studies are predictive analyses based on many analytical assumptions and limited empirical data rendering the strength of evidence weak. Benefits were greatest with EHRs that offered multiple functionalities and when they were implemented in large organisations that may benefit from economies of scale. The literature review did not identify cost–benefit studies for EHR implementation in small organisations. Additionally, costs may be underestimated since most of the analyses did not include implementation costs, which can potentially be 1.5 times the cost of the EHR system itself.

We refer interested readers to our interactive evidence database to learn more about these studies at <http://healthit.ahrq.gov/tools/rand>

In this update we identified five cost-effectiveness or cost–benefit analyses (Bu et al 2007; Kaushal et al 2006; Kopach et al 2005; Maviglia et al 2007; Ohsfeldt et al 2005). None of the studies evaluated fully functional EHRs; what they did was focus on the costs and benefits of one aspect of HIT. Two studies were evaluations of CPOE. The first was a return on investment study of the hospital CPOE system at Brigham and Women's Hospital. Costs were determined through a review of internal documents and interviews with the developers, and included costs associated with hardware, software, networking, leadership and training. Benefits were estimated for each intervention and based on hospital benefit data from the published literature, institutional key informants and internal documents. For example, benefits were estimated for guidance/decision support related to a number of clinical situations (for example, renal dosing), nurse and physician time utilisation and adverse drug event (ADE) monitors. The authors estimated that the CPOE system resulted in a net benefit of US\$16.7 million over 11 years. It took five years to realise a net benefit and more than seven years to realise an operating budget benefit (Kaushal et al 2006).

The second study was a simulation study to estimate the costs of implementing CPOE in hospitals throughout the state of Iowa in the USA. Based on their models which included hospital-specific data such as number of beds, current state of hospital IT infrastructure and the costs of a CPOE system (obtained from a vendor), they estimated that CPOE implementation would dramatically increase operating costs for rural and critical access hospitals with more modest impacts on urban and rural referral hospitals, but that modest benefits would be sufficient to offset CPOE costs (Ohsfeldt et al 2005).

A third study from Partners evaluated the costs and benefits of a barcode medication-dispensing system within its tertiary care hospital pharmacy that used a pre–post design. Costs included software development, hardware purchases, changes to infrastructure, pre-implementation and implementation costs. The primary benefit was cost savings associated with preventing ADEs. Because of a significant decrease in ADEs over the 5 years of the study, the authors estimated a net benefit of \$3.49m with the ‘break-even’ point occurring during the first quarter of year 4, which corresponded to the first year of operation for the system (Maviglia et al 2007).

Another study used computer modelling to project the benefits of IT-enabled disease management for patients with type 2 diabetes mellitus in the USA. The authors evaluated several different technologies including diabetes registries, computerised decision support, remote monitoring, patient self-management and payer-based systems. In their model all of the technologies resulted in lower healthcare utilisation with some having more significant impact on processes and outcomes of care that could translate into decreased morbidity and mortality for patients. This study did not attempt to estimate the costs associated with wide deployment of these technologies on a national level (Bu et al 2007).

The final study estimated the potential cost-effectiveness of an automated medical documentation system for hospital discharge summaries compared with using a traditional transcription system. Their estimates indicated that the automated system would cost more (33.1 cents/discharge), but would result in a decrease in average completion time for discharge summaries (one day).

In this update we found a very small number of new studies focused on cost-effectiveness or cost–benefit analysis, none of which provided new insights into the costs and benefits of implementing fully functional EHRs. Additionally, most of the studies were simulation studies. Only two studies, from the same institution, used empirical data for their estimates.

Our evidence syntheses suggest several directions for future research that could strengthen economic evaluations about HIT implementation. Some investigators were able to successfully acquire empirical data for their cost estimates that contributed to the validity of their analyses. Future studies should focus on performing similar or improved cost data collection methods. We identified earlier that there appears to be a positive relationship between the quality of the implementation and the effects on the costs and the benefits of information technology. Future economic evaluations should place more emphasis on documenting and quantifying the implementation process and the resource implications of various enabling factors such as leadership support. This will allow better delineation of actual costs and of the conditions required to reap the greatest benefits. Likewise, future research should attempt to describe and model how the information system, especially a fully functional EHR, is adapted to support clinical decision-making, workflow processes and health service utilisation. Such research could inform the operational mechanisms of HIT costs and benefits for those contemplating similar types of HIT adoption. Finally, for research evaluating the ROI of HIT implementation, the degree and type of healthcare financing – which is a critical element in the ROI equation – should be accounted for in a more explicit way.

## Summary

Our conclusions for this update mirror those from our prior review: while there is some empirical evidence to support the positive economic value of an EHR system and the component parts of EHRs, realising the projected benefits will require proper alignment of the healthcare financing system, strong leadership, effective implementation strategies and focused efforts to successfully adapt the EHR system.

### **Theme 5: There has been modest progress in identifying or reporting on barriers to adoption**

At the time of our prior review we identified 20 publications that focused on the barriers to implementing HIT. Of these, 8 reported the actual or potential barriers encountered with specific HIT implementations (Abookire et al 2000; Ammenwerth et al 2003; Burkle et al 1999; Cameron et al 1999; Elbourne et al 1987; Gamm et al 1998; Kian et al 1995; Murff et al 2001; Overhage, Perkins et al 2001; Overhage, Suico et al 2001; Wong et al 2003), usually as part of an article discussing implementation. Two articles were short opinion pieces about potential barriers from the physician's perspective (Berkowitz 1997; Lazarus 1999). Two studies assessed the physician time for order entry using CPOE compared with paper methods (Bates et al 1994; Overhage, Perkins et al 2001) and both demonstrated that CPOE took more physician time, although the study by Overhage and colleagues found this additional time to be modest. A third study assessed the effect on primary care physicians' time before and after implementation of an EHR system and reported that the time for a patient visit actually fell by half a minute with EHR use (Pizziferri et al 2005). One study compared physician user satisfaction with two HIT systems: the VA CPRS system and the Mt. Sinai hospital physician order entry system. This study found CPRS users to be much more satisfied than Mt. Sinai hospital users across a number of factors. It also demonstrated that satisfaction was correlated most strongly with the ability of the HIT system to perform tasks in a 'straightforward' manner (Murff and Kannry 2001). Finally, one article was a systematic review of physician use of electronic retrieval systems such as Medline (Hersh and Hickam 1998).

The other five articles from our prior review focused more broadly on barriers to HIT implementation. One systematic review (Johnson 2001) summarised barriers mentioned in the medical and paediatric literature that are significant for paediatric practices. These barriers were divided into four categories:

- Situational barriers included time and financial pressures, unproven ROI, insufficient access to the Internet or to computer technology in an office, the prohibitive cost of information technology for small practices and software not supporting paediatric practice needs.
- Cognitive and or physical barriers included physical disabilities and insufficient computer skills.
- Liability barriers included confidentiality concerns.
- Knowledge and attitudinal barriers included insufficient research about information technology in paediatrics, insufficient knowledge about benefits provided by information technology, apprehension about change and philosophical opposition to information technology.

Two studies used surveys to identify barriers in the use of EMRs (Miller and Sim 2004) and barriers to implementing CPOE systems in US hospitals (Poon et al 2004). In the first of these studies the authors conducted 90 interviews with EMR managers and physician champions in 30 physicians' organisations between 2000 and 2002. Key barriers to the use of EMR were high initial financial costs, slow and uncertain financial payoffs, and high initial costs in terms of physician time. Additional barriers included difficulties with technology, complementary changes in support, electronic data exchange, financial incentives and physician attitudes. The authors note that these barriers were most acute for physicians in solo or small group practices, which account for a large proportion of US physicians. The second article (Poon et al 2003) reported the results of 52 interviews at 26 hospitals in various

stages of implementation of CPOE – from not considering implementation to fully implemented. Most respondents were chief information officers with the remainder consisting of chief financial officers, chief medical officers and other management officials. The authors identified three main barriers to adopting CPOE. The first was physician and organisational resistance due to the perceived negative impact on the physician's workflow. They noted that resistance from physicians could escalate to the point of a 'physician rebellion', which could derail the entire implementation process. The second barrier was the high cost, with estimates from prior studies for the cost of CPOE ranging from \$3–10m depending on the hospital's size and the level of existing information technology infrastructure. The third major barrier was product/vendor immaturity. Survey respondents reported that many current vendor products did not fit the needs of their hospital, and extensive software modifications were required to accommodate established workflow in the hospital.

We also identified two recent prominent editorials about barriers to HIT implementation that summarised the issues succinctly (Hersh 2004; Wears and Berg 2005). The first of these (Hersh 2004) identified several challenges for adoption of electronic health records. These included cost, technical issues, system interoperability, concerns about privacy and confidentiality and a lack of a well-trained clinical informatics workforce to lead the process. This author identified financing as the biggest impediment, which he attributed to a misalignment of costs and benefits. He noted that while some studies have suggested a substantially positive return on HIT investment for the healthcare system as a whole, organisations and individuals that are expected to pay for the systems see only about 11 per cent of return on their investment. The rest of the savings accrue to those who typically do not pay directly for the EHR. Another major challenge he identified was system and data interoperability, noting that most healthcare data (whether on paper or electronic) are trapped in 'silos'. A third concern was privacy and confidentiality: the author stated that physicians, other healthcare professionals and healthcare organisations must be vigilant in protecting patient privacy. The last major barrier he identified was the need for a workforce capable of leading the implementation of information technology.

The second editorial (Wears and Berg 2005) stated that, despite predictions of a 'bright and near future' for the use of HIT, this future never seems to be realised. The authors attributed the lack of progress in HIT implementation to a lack of attention to the social component, citing the need to view the clinical workplace as a complex system in which technologies, people and organisational routines interact dynamically. This leads to the following observations:

- 'Organizations are simultaneously social (eg consisting of people, values, norms and culture) and technical (ie without tools, equipment, procedures, technology and facilities the people could not work and the organization would not exist).
- These social and technical elements are deeply inter-dependent and inter-related – hence the term socio-technical systems. Every change in one element affects the other.
- Accordingly, good design and implementation is not a technical problem but rather one of jointly optimizing the combined socio-technical system.'

The authors also note that 'information technology in and of itself cannot do anything, and when the patterns of its use are not tailored to the workers and their environment to yield high-quality care, the technological interventions will not be productive. This implies that any IT acquisitions or implementation trajectory should, first and foremost, be an organization change trajectory.'

In summary, in our prior review we identified 20 studies regarding barriers to the implementation of HIT. These barriers can be classified as situational barriers (including time and financial concerns), cognitive and or physical barriers (include physical disabilities and insufficient computer skills), liability barriers (including confidentiality concerns) and knowledge and attitudinal barriers. In addition to these barriers a principal theme of our earlier review was that most published HIT studies were lacking in descriptions

of factors felt to be important in understanding implementation. This reflects the relative weakness of our knowledge of the factors important in quality improvement initiatives and organisational change.

Since our prior review there has been modest progress on evaluating barriers to implementation or adoption of HIT. We identified 45 articles that reported information on barriers and/or adoption. While many of these articles mentioned information on barriers only in passing (such as cost barriers, attitudinal barriers, computer hardware or software-related barriers and other technical barriers), 14 reported more specifically on barriers and adoption. We discuss them here briefly.

Cutler and colleagues assessed the adoption of CPOE as at 2003 by examining data from the Leapfrog Group's Hospital Patient Safety Survey (Cutler et al 2005). Despite the literature on CPOE's benefits in terms of helping to prevent ADEs, full implementation of CPOE was achieved by only 2.7 per cent of respondents to the survey. Hospital ownership was strongly correlated with CPOE, with government hospitals (other than VA) being most likely and for-profit hospitals being least likely to have implemented CPOE. Regarding EHR adoption, a summary of the published evidence estimated that, as at 2005, about 24 per cent of US physicians used EHRs in the ambulatory setting while about 5 per cent of US hospitals used CPOE (Jha et al 2006).

In Australia, a national stratified random sample of 3000 GPs in primary care settings conducted in 2005 found that 90 per cent of respondents used a clinical software package – 85 per cent of respondents used it for ordering laboratory tests and 64 per cent used it for recording progress notes (McInnes et al 2006). This survey was limited by a low response rate (40 per cent).

A survey of US paediatric practices found that, in 2005, 21 per cent of practices had an EHR and that this proportion increased with larger practice sizes (32 per cent in large practices versus 3.5 per cent in solo practitioners) (Kemper et al 2006). About half of the other practices had plans to implement an EHR in the future. Perceived barriers to adoption included physician resistance (77 per cent of practices without an EHR reported this barrier), system downtime (72 per cent), increase in physician time (64 per cent), providers having inadequate computer skills (60 per cent), cost (94 per cent) and an inability to find an EHR that met the practice's requirements (81 per cent). Interestingly, among practices without an EHR, 22 per cent reported a 'bad previous experience with an EHR' as a barrier, indicating a failed implementation.

Related to this finding, one survey targeted all US users of CPOE to assess the presence and type of 'unintended consequences' (Ash et al 2007). Ash and colleagues received survey responses from 176 of 472 hospitals thought to have implemented CPOE. Eighty per cent of respondents reported that CPOE implementation was 'moderately to very important' in producing 'things that happened that you didn't expect' in the categories of workflow changes, system demands, communication, emotions ('Have you seen users express strong feelings about CPOE?') and dependence on the technology ('If your computer went down would this be a significant issue for your organisation?'). Many of the free-text responses Ash and colleagues received exemplified the challenges facing institutions trying to implement HIT (for example, 'it takes an army to build and maintain the system, assuming you have not hired the vendor to do this work' and 'computer phobics had a hard time, they identified each additional minute the physicians spent because of the system').

Another US survey included physicians who already subscribed to an online Internet service that has since become part of WebMD (n=1,004 respondents or only about 3.7 per cent of physician members) (Pizzi et al 2005). Characteristics of physicians using electronic prescribing, compared with physicians not using electronic prescribing, included being generalists, working within academic medical centres or publicly-funded health centres and being modestly younger. Non-users were significantly less likely than users to agree with the statements 'e-prescribing can save time in writing prescriptions', 'e-prescribing

can reduce medication errors' and 'e-prescribing can improve physicians' ability to monitor patients' drug therapy', among other statements. Cost was the most identified barrier to adoption. Lastly, a national survey of US healthcare organisations with at least 20 physicians (response rate = 70 per cent) found that only about half of organisations had a registry for even one chronic illness, and half of these registries were not linked to clinical data (Schmittziel et al 2005). Factors associated with registry use included, for example, public recognition for quality, size (200 or more doctors in the organisation), ownership of the organisation and being a medical group. Published since our review was completed, but noted here for its breadth and impact, was a survey of US physicians that looked at adoption and barriers. Among the 2,758 respondents (62 per cent response rate), only 4 per cent reported having a fully functional EHR system, while 13 per cent reported having a 'basic' system (meaning that the system did not need to include most order entry functions or decision support). Consistent with other studies, larger practices were statistically more likely to have an EHR than smaller ones, as were primary care practices compared with specialty ones. However, absolute differences between groups were small (for example, 6 per cent of primary care practices versus 4 per cent of specialty practices reported having a fully functional system). As in most other studies, cost was the most identified barrier to adoption; new to this study was that financial incentives for the purchase and use of the system were the most frequently cited facilitator for adoption (DesRoches et al 2008).

A second group of papers assessed more regional samples. A survey of physicians belonging to the Connecticut State Medical Society Independent Practice Association found that, in 2006, 16 per cent of physician offices used an EHR, 9 per cent of offices used e-laboratory systems and 7 per cent used e-prescribing systems (Mattocks et al 2007). The most commonly stated barrier was cost (72 per cent); other barriers were the time it takes to train staff (40 per cent), lack of proficiency among staff (26 per cent) and lack of an information technology culture within the office (18 per cent). A survey of primary care physicians at Kaiser Northwest (49 per cent response rate), which was designed to assess explanations for low rates of appropriate responses to computerised clinical decision support embedded in their EpicCare EHR system, reported that most clinicians thought that the decision support helped them provide better care and was worth the time. However, 80 per cent of respondents said they were less likely to accept alerts if they were behind schedule, a situation that 84 per cent of clinicians admitted to being in 'some', 'most', or 'all of the time'. A survey of physicians regarding CPOE at two Massachusetts hospitals (71 per cent response rate) found that only 22 per cent of respondents thought the system's user interface supported their workflow. Only 37 per cent of respondents believed it was faster to use CPOE than to hand write orders, and only 41 per cent believed CPOE helped them to carry out an order more rapidly (Lindenauer et al 2006). However, a majority of respondents recognised that CPOE had safety advantages. A survey in Florida regarding adoption of EHR and barriers (28 per cent response rate) found that 'imminent adopters' – meaning physicians planning to adopt an EHR within the coming year – were more likely than other physicians to work in larger practices, be in a multi-specialty practice and be slightly younger (Menachemi 2006). The primary barrier to adoption was cost among those physicians not considering EHR adoption. The last paper in this set was a description of the views of many staff at a Norwegian hospital that had gone 'near paperless' (Lium et al 2006). Compared with a survey done when both the EHR and paper-based record co-existed, after going 'near paperless' (a process that included scanning all old paper-based medical records), nurses reported increased use of the EHR and that 14 of the 19 tasks they did were now more effective. Medical secretaries were most satisfied with the EHR, followed by nurses and physicians.

The last two papers in this theme were case studies of adoption of HIT. The first assessed the use of an Internet-based DSS for prescribing antibiotics (this was not part of an EHR). In five rural hospitals compliance with use of the DSS for patients admitted with community-acquired pneumonia was less than hoped for in three out of the five studied (Stevenson et al 2005). Further examination revealed that existing cultural differences strongly discouraged the questioning of physician orders by non-physicians (in this case, the pharmacist or nurse who consulted the DSS). A non-physician intermediary was tested because an earlier study found that physicians were reluctant to access the Internet-based system because of the perceived length of time required to log on and run the programme, and the lack

of terminals in patient care areas. It was felt that using a non-physician to do the task of running the DSS would overcome this problem, but local cultural issues prevented any uptake at three of the five hospitals.

The second study in this group, and the most sophisticated and influential one, was a case study of the implementation of an EHR in a Swedish hospital (Ovretveit et al 2007). This was informed by Roger's Theory of the Diffusion of Innovation and a prior study of Kaiser in the USA. It concluded that the successful implementation of the EHR at this hospital included:

- consultation before implementation
- consensus about the need for a system and which system was best
- prioritisation and 'drive' by the management team
- competent IT project leader and team
- tested, user-friendly and intuitive system that could be used with little training
- potential for development of the system
- medication order entry not difficult to integrate after implementation (CPOE was not part of the initial implementation).

The authors compare and contrast their findings to expectations based on Roger's theory, finding good concordance, and with factors postulated by previous research. The authors further note: 'The evidence from this and other research is that an [EHR] designed to meet many different needs often does not meet local clinical work needs, is more difficult to implement, and can reduce productivity and access to information critical for patient care and safety'. The authors conclude with 'suggested general lessons' for others contemplating implementing an EHR in a hospital:

- choose a system which allows a range of needs to be met and is tried and tested in a similar setting
- the overriding choice criteria should be for a system that works for clinical personnel and saves time
- the system should be intuitive, and require little training
- the system should be easy to modify and develop, within limits, for different departments and uses
- the decision about the system should be participatory, but once made implementation should be directed and driven
- balance local control of selection, implementation and clinical participation with meeting higher-level requirements
- involve each level in different ways, with clear and appropriate parameters about which decisions can be made locally and which require higher level decisions about common standards
- assess and address the presence and absence of prior and concurrent factors, which have been repeatedly shown in research to help and hinder implementation.

### **Summary**

An increasing number of published studies report on the adoption of HIT and barriers. These studies mostly show that adoption is lower than desired and that the key barriers are cost, perceived difficulties

using the system and perceptions of adverse effects on work. Larger healthcare organisations and ones other than for-profit are more likely to adopt HIT. The most sophisticated analysis to date about factors important for implementation concludes that two important factors are to 'choose a system which allows a range of needs to be met and is tried and tested in a similar setting' and 'the overriding choice criteria should be for a system that works for clinical personnel and saves time'. As we have previously documented, the proportion of HIT articles that report information on variables vital to assess whether a published report involves 'a similar setting' is very small, and the evidence on 'saving time' and 'works for clinical personnel' (the human factors) is also tiny, leaving policy-makers and others considering implementation of an HIT in the dark about what kind of system to get and how to best go about successfully implementing it.



## Chapter 4. Discussion and conclusions

### Limitations

The primary limitation of this review is the quality and quantity of the available studies. Understanding the benefits and costs of implementing a HIT system requires knowledge of the following components:

- technical
- human, including project management skills
- organisational – this includes an organisation's past and current culture of change, and its financial situation.

In our initial review this information was absent from most of the published studies of HIT. Unfortunately, little has changed in the two years since our first review. Past limits on word count may have prevented some authors from including this information in their published reports. However, recognition that this information is necessary to help evaluate HIT systems and the recent practice of allowing supplementary methodological information to be posted online should obviate the problem.

The second limitation is that, while our search efforts were comprehensive, we may not have found all the relevant studies. We selected only articles that were classified as systematic reviews, hypothesis-testing studies or predictive analyses for more detailed review and inclusion as structured abstracts in our interactive database. These articles tend to have less description about how the HIT actually operated and its implementation processes than do qualitative descriptive articles, although in general we did not find good evidence of such critical information during our review processes. We also note that while these qualitative articles might contain more contextual information about the HIT systems, they are completely lacking in any generalisable knowledge about the benefits of HIT such as reduction in errors or quality improvement. Any studies that compared outcomes (such as error rates) with and without a HIT system would have been classified as hypothesis-testing studies and thus included in our analyses. However, it is conceivable that there may be descriptions of contextual and implementation factors that could be linked with hypothesis-testing studies of the same systems that are described in separate publications. An advantage of our interactive database of evidence (<http://healthit.ahrq.gov/tools/rand>) is that it can be updated easily, so we invite readers to send us the citations for relevant articles we may have missed.

A third limitation is that we considered only published studies. Of course, the experience of some healthcare organisations with commercial HIT systems may never be published. For example, we learned of the experiences Geisinger healthcare system had of implementing EpicCare, but found no peer reviewed publications that described this. Similarly, problems with HIT implementation at Kaiser and Cedars-Sinai Medical Center have been reported only in the lay press. Therefore, we know that relevant experience is going unreported; more needs to be done to encourage publication of these experiences.

The fourth and final limitation is that many of the costs and financial benefits of EHRs will change over time because they depend on the changing price of factors such as hardware, software, labour costs and medical prices. Consequently, it is difficult to translate costs from when they were reported originally into current prices.

## Conclusions

- Predictive analyses, based on statistical modelling techniques, suggest that HIT has the potential to enable a dramatic transformation in the delivery of healthcare by making it safer, more effective and more efficient. The empirical research evidence base supporting HIT benefits is more limited.
- However, this update has revealed a modest increase in our knowledge about the factors associated with successful implementation. These include:
  - choose a system that is intuitive to use and that requires little training for users
  - choose a system that can be modified and developed easily
  - ensure that the decision-making process for developing or selecting a system is participatory, but once this decision has been taken ensure that implementation is directed and driven.

These findings need to be tested in other settings to understand the degree to which they are generalisable.

- Organisations that have realised some of these major gains through the implementation of multifunctional, interoperable HIT systems built around an EHR include the US Department of Veterans Affairs, Partners, the Regenstrief Institute, Intermountain Health and Vanderbilt. In the past two years these institutions have continued to publish studies showing the benefits and limitations of multifunctional EHR systems.
- The specific context within which HIT is implemented – including the setting, the clinical issues and the patient populations – greatly influences its use and effects. The impact of HIT implementation on cost and quality will not be consistent across institutions, independent of context.
- More widespread implementation of HIT is limited by the lack of generalisable knowledge about what types of HIT and methods of implementation will result in changes in benefits and costs for specific health organisations, especially for small practices and small hospitals.
- Reporting of HIT developments and implementations needs to be improved. This includes providing more description of both the intervention and the organisational and economic environment in which it is implemented.
- A high priority must be placed on establishing standards for the information that needs to be measured and reported in HIT implementation studies, similar to the Consolidated Standards of Reporting Trials (CONSORT standards) for clinical trials of therapeutic interventions.
- There is an increasing number of HIT applications that are designed to be accessed directly by the patient. In particular, there is a large number of Internet self-help sites about which little is known in terms of use and outcomes.
- Models can be built to estimate the costs and benefits of interoperable HIT systems within and across healthcare provider settings and payers/purchasers and, cumulatively, across the healthcare continuum, but these models are based on many assumptions.
- Implementation of HIT faces many barriers – principally these are cost and overcoming misgivings from physicians due to perceived adverse effects on their time.

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## Appendix A: Search strategies

### HIT update – search methodologies (searches performed 30/3/2007 and 2/4/2007)

Database searched and time period covered: PubMed, 2004–2007

Other limiters: English

Search strategy (Improvement):

automatic data processing[majr] OR medical informatics[majr] OR medical informatics applications[majr]  
OR public health informatics[majr] OR electronics, medical[majr] OR information technolog\* OR  
information infrastructure\* OR ehealth OR e-health

AND

outcome assessment health care OR process assessment health care OR workplace OR workflow\* OR  
work flow\* OR quality indicators, health care

AND

improv\*[tiab] OR chang\*[tiab]

NOT

[automatic data processing[majr] OR medical informatics[majr] OR medical informatics  
applications[majr] OR public health informatics[majr] OR electronics, medical[majr] OR information  
technolog\* OR information infrastructure\* OR ehealth OR e-health

AND

adverse effects[sh] OR outcome and process assessment health care[mh] OR costs and cost analysis  
OR efficiency, organizational OR risk assessment OR outcome\*[tiab] OR cost[tiab] OR costs[tiab] OR  
efficien\*[tiab] OR risk\*[tiab] OR risks[tiab] OR adverse[tiab]

AND

systematic[sb] OR systematic review\*]

Number of items retrieved: 581

=====  
Database searched and time period covered: CINAHL, 2003–2007

Other limiters: English

Search strategy:

((computers and computerization) or computer systems or computerized patient record).mp. or  
computerization.ti. or computer.ti. or computers.ti. or informatics.mp. or information systems.mp. or  
information technology.mp. or information infrastructure.mp. or ehealth.mp. or e-health.mp. or internet.  
mp. [mp=title, subject heading word, abstract, instrumentation]

AND

(outcome\$ or effect or effects or cost or costs or efficient or efficiency or effective or fail or fails or failure  
or risk or risks).mp.

AND

(systematic review or meta analysis or metaanalysis).mp.

NOT

website or websites or web site\$ or education).mp.

Number of items retrieved: 69  
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Database searched and time period covered: Periodicals Abstracts, 2005–2007

Search strategy:

(de: information and de: technology) or (de: information and de: systems) or de: computer+ or de: digital or de: electronic or de: internet)

AND

de: health or de: healthcare or de: medical or de: medicine or de: physician+ or de: doctor+ or de: hospital+

Number of items retrieved: 1006

### **HIT update – search methodologies (searches performed 18/5/07)**

Database searched and time period covered: PubMed, 2004–2007

Other limiters: English

Search strategy #1 (effects and outcomes):

automatic data processing[majr] OR medical informatics[majr] OR medical informatics applications[majr] OR public health informatics[majr] OR electronics, medical[majr] OR information technolog\*[tiab] OR information infrastructure\* OR ehealth OR e-health

AND

adverse effects[sh] OR outcome and process assessment health care[mh] OR costs and cost analysis OR efficiency, organizational OR risk assessment OR outcome\*[tiab] OR cost[tiab] OR costs[tiab] OR efficien\*[tiab] OR risk\*[tiab] OR risks[tiab] OR adverse[tiab]

NOT

Image Interpretation, Computer-Assisted OR surgery, computer-assisted/methods OR diagnosis, computerized/methods OR Radiotherapy Planning, Computer-Assisted/methods OR Radiotherapy, Intensity-Modulated/methods OR radiometry/methods OR Imaging, Three-Dimensional/methods OR Video-Assisted Surgery/methods OR Diagnosis, Computer-Assisted/methods OR Radiotherapy/methods OR Therapy, Computer-Assisted/methods

NOT

letter[pt] OR editorial[pt] OR news[pt]

Number of items retrieved: 3857

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### Search strategy #3: (Improvement)

automatic data processing[majr] OR medical informatics[majr] OR medical informatics applications[majr]  
OR public health informatics[majr] OR electronics, medical[majr] OR information technolog\*[tiab] OR  
information infrastructure\* OR ehealth OR e-health

AND

outcome and process assessment health care[mh] OR workplace\* OR workflow\* OR work place\* OR  
work flow\* OR quality indicators, health care

AND

improv\*[tiab] OR chang\*[tiab]

NOT

letter[pt] OR editorial[pt] OR news[pt]

NOT

results of Searches #1 or #2

Number of items retrieved: 381

### HIT update – search methodology (search performed 8/6/07)

Database searched and time period covered: PubMed, 2004–2007

Other limiters: English

Search strategy:

automatic data processing[majr] OR medical informatics[majr] OR medical informatics applications  
OR public health informatics[majr] OR electronics, medical[majr] OR information technolog\*[tiab] OR  
information infrastructure\* OR ehealth OR e-health OR information systems OR computer-based[tiab]  
OR computer based[tiab] OR artificial intelligence OR computerized alert\* OR computerised alert\*  
OR computerized reminder\* OR computerised reminder\* OR informatic\*[tiab] OR therapy, computer-  
assisted OR computerized decision\* OR computerised decision\* OR electronic health information  
OR electronic prescribing OR decision making, computer-assisted OR telerobotic\* OR telemedicine  
OR electronic health record\* OR electronic medical record\* OR computerized physician order entry  
OR computerised physician order entry OR computer provider order entry OR cpoe OR diagnosis,  
computer-assisted[majr] OR computer-assisted[tiab] OR computer assisted[tiab] OR electronics,  
medical OR informatic\*[tiab]

AND

adverse effects[sh] OR outcome and process assessment health care[mh] OR costs and cost analysis  
OR efficiency, organizational OR risk assessment OR outcome\*[tiab] OR cost[tiab] OR costs[tiab] OR  
efficien\*[tiab] OR risk\*[tiab] OR risks[tiab] OR adverse[tiab] OR quality OR benefit\*[tiab] OR financial OR  
economic\* OR error\* OR harm\* OR dissatisf\* OR satisf\* OR medication errors OR patient satisfaction  
OR side effect\* OR safe\*

NOT

Image Interpretation, Computer-Assisted OR surgery, computer-assisted/methods OR diagnosis,  
computerized/methods OR Radiotherapy Planning, Computer-Assisted/methods OR Radiotherapy,  
Intensity-Modulated/methods OR radiometry/methods OR Imaging, Three-Dimensional/methods  
OR Video-Assisted Surgery/methods OR Diagnosis, Computer-Assisted/methods OR Radiotherapy/  
methods OR Therapy, Computer-Assisted/methods OR medical education OR patient education OR  
surgery, computer-assisted/instrumentation OR computer-assisted telephone interview\* OR computer-  
assisted interview\* OR bioinformatic\* OR gene OR genetic\* OR biology OR biological

NOT

letter[pt] OR editorial[pt] OR news[pt]

Number of items retrieved: 1133



## Appendix B. Health information technologies pre-screening form

Article ID: \_\_\_\_\_

Last Name of First Author: \_\_\_\_\_

Reviewer: \_\_\_\_\_

Check all that apply on each question. To change pre-screener data from “checked” to “unchecked” please write “uncheck” next to the appropriate box.

**1. What is the article’s purpose?**  
[Circle one]

**Descriptive**

1. Qualitative [**STOP**]      2. Quantitative  
3. Other descriptive

**Hypothesis testing:**  
With Intervention, with concurrent comparison group:

4. RCT      5. CCT      6. Cntrl. Before/After

**With intervention, without concurrent comparison group:**

7. Pre-Post      8. Time series  
9. Historical control

**No intervention**

10. Cross-sectional  
19. Case study with concurrent control

**Other hypothesis testing:**

11. Other hypothesis testing  
20. Case control      21. Cohort

**Predictive analysis**

12. Cost-effect.      13. Cost-benefit  
14. Other pred.analysis

**Review**

15. Non-systematic [**STOP**]  
16. Systematic/MA  
Other Purpose  
18. Other (specify: \_\_\_\_\_) [**STOP**]

**2. Are barriers or facilitators the main focus of the paper and are numerical results given?**  
[Circle one]

Yes \_\_\_\_\_ 1  
No \_\_\_\_\_ 2  
N/A, N/R \_\_\_\_\_ 8

[**STOP** if #1 = 1, 2, or 3 & #2 = No or N/A, N/R]

**3. What are the one or two main HIT elements being tested?**

- Computerized Provider Order Entry \_\_\_\_\_
- Electronic Health Record \_\_\_\_\_
- Decision Support \_\_\_\_\_
- Results Reporting/Viewing Systems \_\_\_\_\_
- Electronic Prescribing \_\_\_\_\_
- Barcoding \_\_\_\_\_
- Mobile Computing \_\_\_\_\_
- Data Exchange Networks/ Community Health Information Network \_\_\_\_\_
- Patient Decision Support/ Consumer Health Informatics \_\_\_\_\_
- Communication Systems \_\_\_\_\_
- Administrative \_\_\_\_\_
- Knowledge/ Information Retrieval Systems \_\_\_\_\_
- Data Collection/ Data Summary Systems \_\_\_\_\_
- Telemedicine \_\_\_\_\_
- Robotics \_\_\_\_\_
- HIT in general \_\_\_\_\_
- Other (specify \_\_\_\_\_) \_\_\_\_\_
- Not HIT \_\_\_\_\_
- N/A, N/R \_\_\_\_\_

**4. Which IOM categories does the HIT address?**

- Health information and data storage \_\_\_\_\_
- Results management \_\_\_\_\_
- Order entry management \_\_\_\_\_
- Decision support \_\_\_\_\_
- Electronic communication and connectivity \_\_\_\_\_
- Patient support \_\_\_\_\_
- Administrative processes \_\_\_\_\_
- Reporting and population health management \_\_\_\_\_
- Other \_\_\_\_\_
- N/A, N/R \_\_\_\_\_

**5. What are the types of healthcare organization settings?**

- Hospital/inpatient \_\_\_\_\_
- Outpatient/ambulatory \_\_\_\_\_
- Integrated delivery Network (IDN) \_\_\_\_\_
- Emergency room \_\_\_\_\_
- Nursing home \_\_\_\_\_
- Patient home \_\_\_\_\_
- Pediatrics \_\_\_\_\_
- Pharmacy \_\_\_\_\_
- Internet \_\_\_\_\_
- Other setting (specify: \_\_\_\_\_) \_\_\_\_\_
- N/A, N/R \_\_\_\_\_

**6. Does this article report data from any of the following systems?**

- Intermountain \_\_\_\_\_
- Partners \_\_\_\_\_
- Regenstrief \_\_\_\_\_
- VA \_\_\_\_\_
- UK's NHS \_\_\_\_\_
- Kaiser \_\_\_\_\_
- Vanderbilt University \_\_\_\_\_
- Other (specify: \_\_\_\_\_) \_\_\_\_\_
- Other (specify: \_\_\_\_\_) \_\_\_\_\_
- Other (specify: \_\_\_\_\_) \_\_\_\_\_
- N/A, N/R \_\_\_\_\_

**7. Which outcomes are measured (numerically reported) in the article?**

- Impact on patient safety \_\_\_\_\_
- Impact on patient satisfaction \_\_\_\_\_
- Impact on health care effectiveness and quality \_\_\_\_\_
- Impact on efficiency, utilization, and costs \_\_\_\_\_
- Impact on healthcare access \_\_\_\_\_
- Other (specify: \_\_\_\_\_) \_\_\_\_\_
- N/A, N/R \_\_\_\_\_

**8. What years did the research take place?**

(Enter 4-digit years. N/A, N/R: enter 9999)

Year began

Year ended

**9. What types of health care conditions are being assessed?**

- Cancer – Lung \_\_\_\_\_
- Cancer – Breast \_\_\_\_\_
- Cancer – Colon \_\_\_\_\_
- Cancer – Prostate \_\_\_\_\_
- Cancer – Other (specify: \_\_\_\_\_) \_\_\_\_\_
- COPD \_\_\_\_\_
- Dementia \_\_\_\_\_
- Osteoarthritis \_\_\_\_\_
- Osteoporosis \_\_\_\_\_
- Depression \_\_\_\_\_
- Diabetes \_\_\_\_\_
- Heart Failure \_\_\_\_\_
- Hypertension \_\_\_\_\_
- Ischemic Heart Disease \_\_\_\_\_
- Stroke \_\_\_\_\_
- Atrial Fibrillation \_\_\_\_\_
- Screening and Prevention \_\_\_\_\_
- Other (specify: \_\_\_\_\_) \_\_\_\_\_
- Other (specify: \_\_\_\_\_) \_\_\_\_\_
- Other (specify: \_\_\_\_\_) \_\_\_\_\_
- Not specified \_\_\_\_\_

**Core EHR functionalities as defined by the Institute of Medicine in *Key capabilities of an electronic health record system (2003)***

Health information and data: EHR must contain certain data about patients in order for providers to make sound clinical decisions (for example, previous lab test results, allergy and medication information, diagnoses, demographics, clinical narratives). Must be presented using well-designed interfaces to avoid data overload

Results management: ability to manage results of all types (for example, laboratory, radiology results) electronically (reduces lag times and increases efficiency, reduces redundancy)

Order entry/order management: computerised provider order entry

Decision support: computerised decision support systems that enhance clinical performance, or help with clinical diagnosis and disease treatment and management

Electronic communication and connectivity: ability for healthcare team members and other care partners (for example lab, radiology, pharmacy) and patients to communicate (that is, email and web messaging, computerised alerts for abnormal labs, integrated health record across settings)

Patient support: computer-based patient education; home monitoring by patients

Administrative processes: electronic scheduling systems, billing and claims, validation of insurance eligibility

Reporting and population health management: ability to abstract data for public and private sector reporting requirements using reliable administrative data (standardised terminology, machine-readable format)