

The impact of health information technology on the quality of medical and health care: a systematic review

Aziz Jamal, Kirsten McKenzie and Michele Clark

Abstract

The aim of this study was to systematically review the published evidence of the impact of health information technology (HIT) or health information systems (HIS) on the quality of healthcare, focusing on clinicians' adherence to evidence-based guidelines and the corresponding impact this had on patient clinical outcomes. The review covered the use of health information technologies and systems in both medical care (i.e. clinical and surgical) and other areas such as allied health and preventive services. Studies were included in the review if they examined the impact of Electronic Health Record (EHR), Computerised Provider Order-Entry (CPOE), or Decision Support System (DS); and if the primary outcomes of the studies were focused on the level of compliance with evidence-based guidelines among clinicians. Measurements considered relevant to the review were either of changes in clinical processes resulting from a change of the providers' behaviour, or of specific patient outcomes that demonstrated the effectiveness of a particular treatment given by providers. Of 23 studies included in the current review, 17 assessed the impact of HIT/HIS on health care practitioners' performance. A positive improvement, in relation to their compliance with evidence-based guidelines, was seen in 14 studies. Studies that included an assessment of patient outcomes, however, showed insufficient evidence of either clinically or statistically important improvements. Although the number of studies reviewed was relatively small, the findings demonstrated consistency with similar previous reviews of this nature in that wide scale use of HIT has been shown to increase clinician's adherence to guidelines.

Keywords (MeSH):

Evidence-Based Practice; Evidence-Based Health Care; Information Systems; Medical Informatics; Quality of Health Care; Review.

Medical and health care systems, both in Australia and internationally, are dynamic and under pressure. As the community demand for quality health care services is increasing, along with the cost of providing these services, burgeoning attention is being directed towards the potential of health information technology (HIT) to lower health care spending and to improve the efficiency, quality and safety of medical care.

The delivery of safe and effective healthcare remains an ongoing challenge to clinicians, particularly as increased attention is being focused on the extent of medical error (Bates, Leape & Callen 1998). Over the past few decades, the aim of many health care systems to improve consistency and safety in patient care has prompted considerable investment in the development of

evidence-based clinical guidelines (Nagykaldi & Mold 2007). However, the effective dissemination of these guidelines has remained a challenging task, and HIT has been proposed as an effective means to implement guidelines in practice (Burstin 2008).

Several benefits of HIT have been well documented in a number of clinical studies. While the advantages of HIT on administrative functions are readily discernible, such as decreasing paperwork and workload of health care professionals, increasing administrative efficiencies, and expanding access to affordable care (Schoen et al. 2006; Hillestad et al. 2005), HIT has also shown effectiveness in preventing medical errors by enforcing clinical guidelines and care protocols (Bates et al. 1998).

Therefore, a systemic review of the literature was conducted to appraise the available evidence on the impact of HIT on the quality of medical and health care. This systematic review aims to contribute to a better understanding of the relationship between HIT and medical practices and other health care, and provide information for stakeholders to promote and maximise the uptake of HIT.

For the purpose of this research, HIT is defined as a broad array of technologies involved in managing and sharing patient information electronically rather than through paper records. These information technologies include the application of health information systems (HIS) designed primarily to support the management of patient's records such as Electronic Health Record (EHR) system, and to assist medical and health care delivery such as clinical decision support system (CDSS) and computerised provider order entry (CPOE) system. Therefore, the terms 'health information technology (HIT)' and 'health information system (HIS)' will be used interchangeably in this review to refer to such electronic systems in health care context.

Methods

Study question and context

This study addressed the question: To what extent does the use of health information technology improve the quality of medical and health care?

In order to be as inclusive as possible the research examined literature discussing the use of health information technologies and systems in both medical care such as clinical and surgical facilities, and other health care such as allied health and preventive services. In terms of quality of medical and health care, we examined specifically clinicians' adherence to evidence-based guidelines and the corresponding impact this had on patient clinical outcomes.

Search strategies

A three-step search strategy was utilised in each component of this review. An initial limited search for literature was performed on English language studies indexed in MEDLINE and CINAHL, followed by an analysis of the test words contained in the title or index terms used to

describe the articles. This strategy was followed by a search for relevant studies using all identified keywords and index terms in a number of electronic databases. For this purpose, a broad set of terms was used to maximise the search strategy's sensitivity. The following terms were used to find relevant studies for the current review:

computer, system*, HIT, electronic, clinical **OR** health **OR** medical or physician **AND** care, physician **AND** decision **OR** support, quality **OR** evidence-based **AND** adherence, electronic health record* **OR** electronic medical record* **OR** electronic patient record*, EHR **OR** EMR **OR** EPR, computerized physician order entry **OR** CPOE **OR** computerized physician order entry.

A Literature search was performed in the following databases: Cochrane library; PubMed; MEDLINE; CINAHL; Database of Abstracts of Reviews of Effectiveness (DARE); EMBASE; ACM Digital Library; Academic Search Premier; Psychology and Behavioural Science Collection; PsycINFO; Science Direct; Austhealth; Multiple database search (which combines – ACM Digital Library, EBSCOhost research databases, EBSCOhost-Academic search premier, Psychology and behavioural science collection, PsycINFO, Science Direct, and Wiley Interscience); and Google Scholar – aimed at finding grey literature in the form of dissertation, conference materials, and other types of publications that meet the inclusion criteria. As HIT/HIS evolved rapidly, the search was limited to the following years (1998 to 2008). Moreover, a literature review drawn from a number of studies prior to 1998 revealed too much failure in integrating HIT/HIS and healthcare processes, due to inadequate design of information systems and their poor performance (Joyce, Green & Winch 2007). Thus, adding studies prior to 1998 may cause an underestimation of the impact of HIT/HIS on the general quality of medical and other health care in this current review.

A search for eligible studies (matching the inclusion criteria) was performed by searching relevant conference proceedings available through internet and electronic databases, as well as reference lists for all eligible papers and reviews identified from cited papers.

Criteria for inclusion of studies**Type of studies**

In addition to randomised controlled trials, other non-randomised research designs such as Controlled Before and After (CBA) and Interrupted Time Series (ITS) studies were included if they evaluated the ability of HIT/HIS to improve an important clinical practice. The latter were also considered for inclusion in a narrative summary to enable the identification of current best evidence regarding the use of health information technology.

Type of user of HIT/HIS

The current review considered the use of HIT/HIS by clinicians, which included physicians, nurse practitioners and allied health professionals directly involved in patient care.

Type of interventions

The current review included studies that examined the effectiveness of the three (3) most common HITs/HISs; namely electronic health record (EHR), Computerized Provider Order-entry (CPOE), and Decision Support System (DS), which includes computerised reminders and alerting systems. Included studies compared the effectiveness of a specific HIT/HIS to either; a manual system (such as paper-based health records), or the same HIT/HIS with additional support functions (such as electronic health record system with reminder); or compared the effectiveness of two different types of HIT/HIS that served the same clinical purpose. Other information systems or technologies used for diagnostic imaging, medical dosage dispensing, and bar-coding for drugs identification were not included in this study.

Type of outcome measures

The outcomes reported in the studies focused on the rate or level of adherence to clinical guidelines among clinicians in providing medical care to a specific group of patients. Adherence to clinical guidelines can be described as the frequency that clinicians complied with and chose to adopt a therapeutic decision that belongs to a specific health care system's recommendations (Bouaud et al. 2001). Therefore, outcomes were either changes in clinical processes resulting from a change of provider's behaviour in delivering medical care that was observed before and after intervention, or specific patient outcomes

that addressed the effectiveness of a particular treatment given by providers supported by evidence-based recommendations from a particular HIT/HIS. In this case, studies that examined the relationship between adherence to clinical guidelines and medication error, resulting from the adoption of HIT or a specific computerised healthcare system, were also considered for inclusion in the current review.

Exclusion criteria

Exclusion criteria applied to studies written in languages other than English, studies published prior to 1998, qualitative studies that drew on the experience of clinicians using health information system or technology in facilitating the uptake of evidence-based guidelines, and other texts such as commentaries and opinion papers.

Data collection and analysis

The title of each study identified by the search strategies was checked for relevance. A total of 36 studies were found in online databases, Google Scholar, and reference lists. Out of 36 studies, only 32 studies were considered relevant on title review. Abstracts of these studies were retrieved and reviewed to determine whether these studies addressed the review questions. All abstracts were read and rated as 'potentially relevant' or 'not relevant'. In this process, studies were rejected due to; not answering the research questions ($n=2$), and studies published prior to year 1998 ($n=3$). Full-text articles were only retrieved for all titles considered to be 'potentially relevant'. Two studies however were only available in abstract form and the researchers had to exclude them in the final review. After reviewing the full-text articles, two studies were rejected due to duplication of data and only 23 studies were finally included in the review. These studies include 8 randomised-controlled trials, 10 time-series studies, 4 systematic reviews and 1 experimental (case scenario) study. The following data were extracted from each study and are presented in Table 1:

- study details
- study design
- type of HIT/HIS and purpose of the study
- primary outcome measured
- key finding.

Studies were reviewed and summarised in tabular and text form. Due to heterogeneity between studies, meta-analysis was not performed.

Evaluation of quality

Studies included in this review were evaluated using standardised critical appraisal instruments from the Joanna-Briggs Institute (JBI) System for the Unified Management, Assessment and Review of Information Package (SUMARI). For randomised-controlled trials, quality assessment was focused on the basis of randomisation and allocation concealment procedures used, as these are the main sources of bias that have been empirically associated with overestimation of treatment effect (Schulz et al. 1995). For this purpose, the JBI Critical Appraisal Checklist for Experimental Studies was used to determine whether the studies have reported sufficient details of randomisation and concealment procedures, and satisfactory attempt to control selection bias has been made. Trials were further rated as: ‘A’ if allocation procedures and attempts to control selection bias were sufficiently reported; ‘B’ if studies did not report

how randomisation was performed and allocation concealed, or reported in insufficient detail to determine whether a satisfactory attempt to control selection bias has been made; and ‘C’ if there was no information about avoidance or attempt to control selection bias.

In addition, JBI Critical Appraisal Checklist for Descriptive Case Series was used to assess the quality of other non-randomised studies included in the current review. For time-series studies, quality assessment was focused on whether or not the study has met three (3) important criteria namely: a rationale for the number and spacing of data points was described or sample size calculation was performed; the primary outcome measure was assessed blindly or was measured objectively; and data was appropriately analysed using time series regression models. Therefore, studies that met all criteria stated above were rated as ‘A’. For studies with insufficient detail to determine whether appropriate data collection procedures were used and analysed using time series regression models, or simply not reported, studies were rated as ‘B’ or ‘C’.

Table 1: Summary of previous research using HIT/HIS to improve quality of medical and health care

STUDY	STUDY DESIGN	PURPOSE (to determine the effect of)	PRIMARY OUTCOME MEASURED	KEY FINDING
Adams et al (2003)	ITS	EHR on the quality of paediatric primary care including preventive	<i>Provider outcome:</i> Number of routine healthcare maintenance topics addressed during hospital visits; clinician assessment of computer-based system	<ul style="list-style-type: none"> Use of EHR was significantly more likely to address 22 over 30 routine health maintenance topics All users of the system reported that its use had improved the overall quality of care delivered, well accepted by families and improved guidance quality
Patkar et al (2006)	EXP	DSS with and without guidelines for assessment of breast cancer patients	<i>Provider outcome:</i> Clinician’s compliance with evidence-based guidelines provided by DSS; Clinician’s assessment of DSS	<ul style="list-style-type: none"> Clinicians made significantly more deviations from guideline without DSS (60/120 errors without DSS and 16/120 with DSS, $p < 0.001$) Opinions of clinicians towards DSS were positive $p < 0.025$
Mullet et al (2001)	ITS	Anti-infective decision support system in paediatric intensive care units	<i>Provider outcome:</i> Antibiotic prescription outside the recommended dosing range; pharmacists intervention for incorrect dosing <i>Patient outcome:</i> Proportion of ICU patients receiving antibiotics	<ul style="list-style-type: none"> 32% relative decrease (from 15.8 to 10.8) in the days that antibiotics were prescribed outside the recommended dosing range 59% relative decrease in a composite measure of need for pharmacist interventions for incorrect dosing 6.3 percentage point of absolute increase (from 60.2% to 66.5% in the proportion of ICU patients receiving antibiotics)
Steele, Eisert, Witter et al (2005)	ITS	DSS for appropriate drugs ordering	<i>Provider outcome:</i> Rate of appropriate drug ordering for 18 high-volume and high risk medications	<ul style="list-style-type: none"> The provider increased ordering the rule-associated lab test when alert displayed (39% at baseline v. 51% after intervention, $p > 0.001$)
Evans et al (1998)	ITS	Computer alert for antibiotics and other anti-infective agents ordering	<i>Patient outcome:</i> Antibiotic-associated adverse drug events (ADEs); number of days of excessive drug dosage	<p>Compare with the 2-y pre-intervention period, reductions were seen on the following:</p> <ul style="list-style-type: none"> Antibiotic-associated ADEs (28 v. 4) Mismatches of infection susceptibility and antibiotic (206 v. 12 eps) Ordered drugs for which a patient had an allergy (146 v. 35 eps) Days of excessive dosing (from 5.9 to 2.7 d)
Chertow et al (2001)	ITS	CPOE with guided medical dosage for inpatients with renal insufficiency	<i>Provider outcome:</i> Rate of appropriate prescription by dose and frequency <i>Patient outcome:</i> Length of stay	<ul style="list-style-type: none"> 21 percentage point absolute increase (from 30% to 51%) in appropriate medication orders (dosing levels or dosing frequency) 4.5% reductions (from 4.5 to 4.3 days) in length of stay

Table 1: continued

STUDY	STUDY DESIGN	PURPOSE (to determine the effect of)	PRIMARY OUTCOME MEASURED	KEY FINDING
Bouaud et al (2001)	ITS	Guideline-based DSS on breast cancer management for drugs prescription	<i>Provider outcome:</i> Physician compliance	<ul style="list-style-type: none"> 23.6 percentage point absolute increase in physician compliance after using the system (from 61.42% to 85.03%)
Teich et al (2000)	ITS	CPOE on physician prescribing practices and adherence to medication formularies	<i>Provider outcome:</i> Medication selection for H2-Blockers; consequent orders for thrombosis prophylaxis; reduction of drug prescribed outside recommended dosing range	<ul style="list-style-type: none"> 66 percentage point absolute increase (from 15.6% to 81.3%, $p > 0.001$) in adherence for all Histamine-Blockers orders 23 percentage point absolute increase (from 24% to 47%) in appropriate use of subcutaneous heparin prophylaxis 1.5 percentage point absolute decrease (from 2.1% to 0.6%) in number of medication doses written that exceeded the recommended maximum
Steele, Eisert, Davidson et al (2005)	ITS	DSS for latent tuberculosis screening	<i>Provider outcome:</i> Appropriate adherence to CDC LTBI screening guideline	<ul style="list-style-type: none"> 16.9 percentage point absolute increase in physician adherence to guidelines for LTBI screening (from 8.9% to 25.2%, $p < 0.001$)
Dexter et al (2004)	RCT	Inpatient computerised provider order-entry system v. computerised reminder for influenza and pneumococcal vaccination administration	<i>Patient outcome:</i> Vaccines administration	<ul style="list-style-type: none"> Pts with standing orders received influenza vaccine sig. more often (42%) than pts with reminders (30%) Pts with standing order received a pneumococcal vaccine sig. more often (51%) than those with reminders (30%) Comp. provider order-entry identified 50% and 22% of hospitalised pts for influenza and pneumococcal vaccination respectively
Kucher et al (2005)	ITS	Electronic alerts to prevent venous thromboembolism among hospitalised patients	<i>Provider outcome:</i> Provider's order for prophylaxis <i>Patient outcome:</i> Risk of deep-vein thrombosis or pulmonary embolism	<ul style="list-style-type: none"> More pts in the intervention group than in the control group received mechanical prophylaxis (10.0% v. 1.5%, $p < 0.001$) or pharmacologic prophylaxis (23.6% v. 13.0%, $p < 0.001$) The computer alert reduced the risk of DVT or pulmonary embolism at 90 days by 41% (hazard ratio 0.59; 95% confidence interval 0.43 to 0.81; $p = 0.001$)
Cannon and Allen (2000)	RCT	DSS on compliance with mental health clinical practice guidelines	<i>Provider outcome:</i> Screening rates for mood disorder; completeness of the documentation of which DSM-IV criteria were met	<ul style="list-style-type: none"> 25.5 percentage point absolute increase (from 61% to 86%) in physician screening for mood disorders with computerised system 94.4 percentage point absolute increase (from 5.6% to 100%) in the rate of complete documentation of DSM-IV criteria
Rollman et al (2002)	RCT	DSS for major depression treatment	<i>Provider outcome:</i> Compliance with reminders for depression diagnosis and treatment advice <i>Patient outcome:</i> Recovery for depressive episodes; HRS-D score (for depression severity)	<ul style="list-style-type: none"> Little differential impact on provider and pts for 3 or 6 months clinical outcomes
Durieux et al (2000)	ITS	DSS for prevention of venous thromboembolism	<i>Provider outcome:</i> Proportion of appropriate prescriptions ordererd for anticoagulation according to pre-established clinical guidelines	<ul style="list-style-type: none"> 12.2 percentage point absolute increase in GP compliance with evidence-based guidelines for drugs (including prophylaxis) ordering (from 82.8% to 94.9%)
Demakis et al (2000)	RCT	Computerised reminder for appropriate ambulatory care	<i>Provider outcome:</i> Compliance with 13 Standard of Care (SOC)	<ul style="list-style-type: none"> 5.3 percentage point absolute increase (from 53.5% to 58.8% in adherence to SOC; OR 1.25 CI 1.08–1.42; $p = 0.002$) 5 of 13 examined care processes were improved
Hetlevik et al (2000)	RCT	DSS for diabetes mellitus treatment	<i>Provider outcome:</i> Physician adherence to recommended care process suggested by decision support system <i>Patient outcome:</i> BP; HbA1c; Cholesterol level; BMI; Risk score for MI	<ul style="list-style-type: none"> No significant change in GPs' behaviour or in pts' outcomes
Eccles et al (2002)	RCT	DSS for management of asthma and angina	<i>Provider outcome:</i> Consultation rate; process of care; prescribing <i>Patient outcome:</i> Perceived health status	<ul style="list-style-type: none"> No effect was found of computerised evidence-based guidelines on management of asthma or angina in primary care
Sequist et al (2005)	RCT	Electronic reminders for diabetes and CAD care	<i>Provider outcome:</i> GPs' compliance with recommended care for diabetes and coronary artery disease	<ul style="list-style-type: none"> Electronic reminders increased the odds of recommended diabetes care (OR=1.3 CI=1.01–1.67) and CAD (OR=1.25 CI=1.01–1.55)
van Wijk et al (2001)	RCT	DSS with evidence-based guidelines on GPs' behaviour for blood test ordering	<i>Provider outcome:</i> Average number of blood tests ordered for order form per practice	<ul style="list-style-type: none"> GPs who used DSS with evidence-based guidelines requested 20% fewer tests
Chaudhry et al (2006)	SR	HIT on quality, efficiency and cost of medical care	Efficiency; effectiveness and safety; adherence and cost	<ul style="list-style-type: none"> Quality improvement: increased adherence to guideline-based care, enhanced surveillance and monitoring and decreased medication errors The major efficiency benefit shown was decreased utilisation of care Data on another efficiency measure, time utilisation, were mixed Empirical cost data were limited
Kawamoto et al (2005)	SR	DSS on clinical practice	System features that are likely to improve clinical practice	<ul style="list-style-type: none"> DSS significantly improved clinical practice in 68% of trials Interventions were likely to succeed if: automatic provision of DSS as part of clinician workflow ($p < 0.00001$); provision of recommendations rather than just assessments ($p = 0.0187$); provision of DSS at time and location of decision-making ($p = 0.0263$), and computer-based DSS ($p = 0.0294$)

Table 1: continued

STUDY	STUDY DESIGN	PURPOSE (to determine the effect of)	PRIMARY OUTCOME MEASURED	KEY FINDING
Delipierre et al (2004)	SR	EHR system on the process of clinical care	Process of care: Length of the consultation hour and content of consultation	<ul style="list-style-type: none"> 26 articles were selected. Use of an EHR was perceived favourably by GPs, with studies of satisfaction being mainly positive. 12 studies evaluating the impact on medical practice and guidelines compliance showed that positive experiences were as frequent as experiences showing no benefit. None of the six studies analysing the impact of CBPRS on pts' outcomes reported any benefit
Hunt et al (1998)	SR	DSS on physician performance and patient outcomes	Drug dosing; diagnosis; prevention and other medical care	<ul style="list-style-type: none"> Effects on physician performance were assessed in 65 studies and 43 found a benefit (66%) 6 of 14 studies assessing patient outcomes found a benefit. Of the remaining 8 studies, only 3 had a power of greater than 80% to detect a clinically important effect

LIST OF ABBREVIATIONS:

1	RCT:	Randomised Controlled Trial	5	EHR:	Electronic Health Record
2	ITS:	Interrupted Time Series study	6	CPOE:	Computerised Provider Order-Entry
3	SR:	Systematic review	7	pts:	Patients
4	DSS:	Decision Support System	8	eps:	Care episodes
			9	EXP:	Experimental study

Results

Description of studies

The current review includes 23 studies, including eight randomised controlled-trials, 10 time-series studies, four systematic reviews and one experimental study with a balanced block design. Studies were conducted in the United States (14), United Kingdom (3), France (3), Norway (1) the Netherlands (1) and Canada (1).

Type and functions of HIT/HIS

Included studies addressed the following types of primary system: clinical decision support aimed at providers, computerised provider order entry, and electronic health records.

The clinical decision support systems were usually embedded in either electronic health record systems, or computerised provider order-entry systems. A clinical decision support system with advanced features however can interoperate with electronic health records system and computerised provider order entry (Chertow et al. 2001; Evans et al. 1998; Steele, Eisert, Witter et al. 2005). Two studies assessed the interventions of stand-alone decision support systems with limited data interoperability, where in these cases the clinicians were required to manually up-date the data generated from the system into an electronic health record (Cannon & Allen 2000; Bouaud et al. 2001). Two studies described the tested systems in insufficient details, and clinician's interaction with the systems was not reported

(Steele, Eisert, Davidson et al. 2005; Patkar et al. 2006).

Three studies assessed the effectiveness of computerised provider order-entry systems (Chertow et al. 2001; Teich et al. 2000; Dexter et al. 2004). These order-entry systems were automatically linked to patients' health records or clinical decision support systems to provide evidence-based recommendation on drug administration, and other services including follow-up treatment and reminders for preventive care.

Electronic health records systems were usually linked with clinical and administrative systems and in most cases a patient's record can be automatically updated. Only one study examined the effectiveness of a stand-alone patient records system over a paper-based records system (Adams et al. 2003). Electronic health records systems with reminders were used intensively by clinicians to screen patients' health risk for diabetes mellitus (Hetlevik et al. 2000), deep vein thrombosis (Kucher et al. 2005; Durieux et al. 2000), latent tuberculosis infections (Steele, Eisert, Davidson et al. 2005) and risk of adverse drug reactions (Teich et al. 2000; Steele, Eisert, Witter et al. 2005; Mullet et al. 2001; Chertow et al. 2001). Additionally, electronic health record systems were usually reported to have an ability to generate a specific report or health summary for guiding clinical staff in delivering medical care (Mullet et al. 2001).

Type of intervention

The major effect of HIS/HIT on quality of care was its role in increasing adherence to guideline or protocol-based care. Five studies assessed the effectiveness of computerised health information systems on drug ordering. These information systems were designed to assist physicians to decide appropriate medication type, dosage, and frequencies according to the patient's health status and existing medical history as stored in the electronic record system. Studies were conducted to assess the impact of new computerised health information systems upon physician prescribing behaviour by measuring the rate of compliance on recommended therapeutic decisions provided by order entry systems, or effect on patient outcomes such as the adverse drug events (ADEs) and length of hospital stay.

Drug ordering studies were mainly time-series or pre-post studies, where the rates of adherence to clinical guidelines were compared before and after the intervention periods. During the control period, standard order-entry systems (usually with limited functionality) were used, and additional functions such as reminder and decision support were added during the intervention period. Only one drug ordering study used a paper-based ordering system as a comparison to the computerised order entry system (Adams et al. 2003).

Four studies assessed the effectiveness of computerised health information systems on preventive care. Health care systems (usually clinical decision support systems) were integrated with electronic health records enabling them to assess a specific health risk according to predefined parameters such as age and vaccination status (Steele, Eisert, Davidson et al. 2005; Dexter et al. 2005). Two studies linked the systems with computerised order-entry that enabled physicians to order for prophylaxis (Kucher et al. 2005; Durieux et al. 2000). Additionally, clinical decision support systems were deployed to assist mental health clinicians to provide care treatments for patients with major depression (Rollman et al. 2002; Cannon & Allen 2000). Other studies covered a diverse range of types of care including medical consultation, diagnosis, follow-up and treatments. Included studies assessed the effectiveness of health information

systems for the management of diabetes mellitus (Hetlevik et al. 2000; Sequist et al. 2005), asthma and angina (Eccles et al. 2002), and ambulatory care according to published clinical guidelines (Demakis et al. 2000). One trial examined the effectiveness of an additional support function that provided evidence-based recommendations for blood test ordering (van Wijk et al. 2001).

Risk of bias in included studies

Of eight randomised-controlled trials included in this review, only two trials reported allocation procedures in sufficient detail to be rated as 'A'. That is, they attempted to control selection bias by using a system whereby treatment allocation could not be known or predicted until participants were enrolled and assigned to a study condition (van Wijk et al. 2001; Rollman et al. 2002). Three studies either did not report how randomisation was performed and allocation concealed, or reported it in insufficient detail to determine whether a satisfactory attempt to control selection bias had been made, and were therefore rated as 'B' (Dexter et al. 2004; Eccles et al. 2002; Demakis et al. 2000). Two trials reported that participants were randomised to treatment according to the healthcare centre (Hetlevik et al. 2000; and Sequist et al. 2005) and randomisation was only done for selected participants where newly referred study participants were not randomly assigned to either control or intervention groups (Cannon & Allen 2000). Therefore, these studies were rated as 'C' due to plausible bias that raises some doubt about the result.

Ten interrupted time-series studies were included in this review. However, none of these studies were rated as 'A' due to poor methodological quality. Six studies were rated as 'B' based on their attempt to report strategies to avoid some threat to internal validity, such as appropriate use of statistical analysis (Kucher et al. 2005; Mullet et al. 2000; Bouaud et al. 2001; Evans, et al. 1998; Chertow et al. 2001; Durieux et al. 2000). The remaining four studies were rated as 'C' due to insufficient detail to determine whether appropriate data collection procedures were used or simply not reported (Teich et al. 2000; Steele, Eisert, Witter et al. 2005; Steele, Eisert, Davidson et al. 2005; Adams et al. 2003).

Quality review of these time-series studies indicated that a majority of the studies did not rule out the threat that another event could have occurred at the same time as intervention. Reporting of factors related to data collection, the primary outcome, and completeness of the data were generally done in a number of studies. However, only one study provided a justification for the number of data points used or a rationale for the shape of intervention effect (Steele, Eisert, Witter et al. 2005). Six interrupted time-series studies included in this review were analysed inappropriately using statistical methods based on ordinary least squares test (Evans et al. 1998; Durieux et al. 2000; Mullet et al. 2001; Chertow et al. 2001; Adams et al. 2003; Patkar et al. 2006). For example, long time-series studies were analysed using simple square-tests and a regression model (Evans et al. 1998; Durieux et al. 2000). In fact, these tests are inappropriate for analysing interrupted time-series designs partly because these methods assume independence of error, and when events or behaviours are measured over time, they usually correlated with each other resulting in biased standard deviations of the parameter estimates (Ramsay et al. 2004). To provide some protection from this threat to internal validity, an appropriate time-series regression model such as an autoregressive integrated moving average (ARIMA) model, which is designed to provide unbiased estimated of error in a series, should be used.

Effects of intervention

Drug ordering studies

The current systematic review identified five studies that assessed systems designed to assist with drug ordering. Two studies assessed the effects of intervention on providers' prescribing practices and patients' outcomes (Chertow et al. 2001; Mullet et al. 2001), three studies assessed the effect on practitioners' performance only (Steele, Eisert, Witter et al. 2005; Teich et al. 2000; Buoaud et al. 2001), and one study focused on patient outcomes (Evans et al. 1998). Guided medication dosing appears to result in improved dose and frequency of choice. In the current review, a significant increase in physician compliance to recommended drug type and dosage were seen in all studies that measured provider outcomes, with improvement from 12

to 66 percentage points absolute. Significant reduction of drugs ordered outside the recommended dosing range was also reported in two studies (Mullet et al. 2001; Teich et al. 2000). In a study conducted by Mullet et al. (2001), guided medical dosing has shown to be effective in reducing the rate of pharmacists' interventions for erroneous drug doses by almost 60%.

Reported patient outcomes were the occurrence of adverse drug events (ADEs), number of days of excessive drug dosage, length of hospital stay, and proportion of ICU patients receiving antibiotics. All studies reported positive outcomes of health care systems being effective in reducing the number of days of excessive drug dosage (Teich et al. 2000; Evans, et al. 1998), length of hospital stay (Chertow et al. 2001) and antibiotic-associated adverse-drug events (Evans et al. 1998). One study demonstrated an increase in the proportion of ICU patients receiving antibiotics due to improved prescription processes (Mullet et al. 2001).

Preventive care

Six studies examined the effect of health information technology on enhancing preventive health care delivery (Steele, Eisert, Davidson et al. 2005; Dexter et al. 2004; Kucher et al. 2005; Durieux et al. 2000; Cannon & Allen 2000; Rollman et al 2002). Studies included measures for primary preventive care (Dexter, et al. 2004), and secondary preventive care (Kucher et al. 2005; Durieux et al. 2000). Two studies assessed screening (Cannon & Allen 2000; Rollman et al. 2002).

Dexter et al. (2004) compared the effectiveness of two computerised systems and found that computerised standing orders were more effective than computerised reminders for increasing both influenza (42% vs. 30%) and pneumococcal (51% vs. 31%) vaccines administration.

Two studies examined the effect of health information technology on secondary preventive care for complications related to hospitalisation. One time-series study was conducted to determine whether presentation of venous thromboembolism prophylaxis guidelines using decision support increased the proportion of appropriate clinical decisions made (Durieux et al. 2000). Results from this study demonstrated a significant increase in physician compliance to guidelines

following the intervention with a 12.1 percentage point absolute increase (from 82.8% to 94.9%; $p < 0.000$) of appropriate prescription. Another study that used computerised surveillance and identification of high-risk patients plus alerts to physicians demonstrated a 3.3 percentage point absolute decrease (from 8.2% to 4.9%) in a combined primary end point of deep vein thrombosis and pulmonary embolism in high-risk hospitalised patients (Kucher et al. 2005).

The review also included two trials that assessed the relative effectiveness of computer and manual reminder systems on the implementation of a clinical practice in the area of mental health. One study found that computerised reminders resulted in a higher screening rate for mood disorders when compared to the manual reminder system (86.5% vs. 61%; $p = 0.008$) with a higher rate of complete documentation from clinical guidelines criteria (100% vs. 5.6%; $p < 0.0001$) (Cannon & Allen 2000). Another study however, showed little or no differential impact on patient's clinical or process outcomes (Rollmen et al. 2002).

One study assessed the effectiveness of computerised clinical decision support system for latent tuberculosis infection (LTBI) screening and found clinicians' adherence to the LTBI guidelines was significantly increased at 16.3 percentage point absolute (from 8.8% to 25.2%; 183% increase, $p < 0.0001$) during the study phase (Steele, Eisert, Davidson et al. 2005).

Other medical care

While most evidence for quality improvement through enhanced adherence to guidelines contained in health information systems focused on preventive care, other studies covered a diverse range of care types. Some tested systems were disease specific, focusing on diabetes (Hetlevik et al. 2000; Sequist et al. 2005), coronary artery diseases (Sequist et al. 2005), asthma and angina (Eccles et al. 2002) or breast cancer among women (Patkar et al. (2006), while others addressed care processes such as ambulatory care services (Demakis et al. 2000), blood test ordering (van Wijk et al. 2001) and management of health records through computerised systems (Adams et al. 2003). Five studies that assessed the impact of computerised systems on practitioner's performance found a benefit

(Sequist et al. 2005; Patkar et al. 2006; Demakis et al. 1998; van Wijk et al. 2001; Adams, et al. 2003). However, computerised systems did not result in a statistically significant change in practitioners' behaviour and patient outcomes in two randomised trials that examined the effectiveness of computerised reminder for treatment of diabetes, coronary artery disease, and asthma and angina (Hetlevik et al. 2000; Sequist et al. 2005; Eccles et al. 2002).

Discussion

To date, the health information technology literature has documented many important quality benefits resulting from the implementation of computerised health information systems. While the impact of HIT/HIS on administrative functions such as decreasing paperwork and workload of health professionals is readily discernable (Schoen et al. 2006; Hillestad et al. 2005), it has become evident that a properly designed information system can become an important tool for preventing medical errors by enforcing clinician adherence to evidence-based clinical guidelines (Bates et al. 1998). In the current review, 14 out of 17 studies that assessed the impact of HIT/HIS on health care practitioners' performance, revealed a positive improvement in relation to their compliance with evidence-based guidelines.

The impact of HIS/HIT on the patient's outcomes however inconsistent as only a small proportion of studies found benefits. For instance, only three studies shown positive improvement and the other five studies revealed either no change or adverse outcomes. Considerable heterogeneity of statistical instruments and data analysis used to assess the corresponding impact of HIS/HIT on patient's outcomes was observed between studies. Included studies that assessed length of stay, proportion of ICU patients receiving antibiotics, rate of adverse-drug events, and rate of patients receiving vaccination as well as perceived health status obtained through a questionnaire, were tested for a statistical significance. Whereas, studies that primarily evaluated the corresponding impact on patient outcomes following routine medical treatments or psychological assessments were only tested for clinical significance (i.e. whether specific treatments

were effective). As acknowledged by the authors, calculations of clinical vs statistical significance represent different outcome measures and hence each study that assessed patient outcomes was assessed with caution.

Overall, the number of included studies was relatively small for reaching a conclusive statement about the effectiveness of HIT/HIS. Nevertheless, the impact of HIT/HIS on clinical practices demonstrated consistency with other reviews (Hunt et al. 1998; Delipierre et al. 2004; Kawamoto et al. 2005; Chaudhry et al. 2006). As has been shown in this review, wide-scale use of HIT/HIS, especially decision support and alerting systems, can increase the clinician's adherence to clinical guidelines. HIT/HIS therefore presents ongoing opportunities to maximise the uptake of research evidence into practice for health care organisations, policy makers and stakeholders.

Strength and limitation of the current review

This study has several important strengths. Firstly, a literature search was undertaken using a comprehensive search strategy. However, only 36 new studies were found. The included studies represented a wide range of medical care and other health services. Therefore, the impact of HIT/HIS on medical and health services can be assessed from different aspects of care. Secondly, included studies covered different study designs. Although it is generally recognised that a well conducted randomised-controlled trial provides more reliable evidence for the effectiveness of a particular intervention, findings from other properly conducted study designs such as experimental and interrupted time series studies can also provide reliable evidence for intervention when a randomised trial is not feasible. Owing to the fact that these study designs are prone to bias, the studies' methodological quality was assessed with caution. For this purpose, a standardised quality assessment checklist for non-randomised studies was used, obtained from the Joanna-Briggs Institute. Therefore, only studies that met the minimum criteria as outlined in the quality assessment checklist were included for final review.

One important limitation of this study relates to the quantity and scope of literature. Although

a comprehensive literature search was performed, only a small number of studies were identified. Inclusion criteria that limit the studies to English-language journal articles might also reduce the chances of finding other relevant studies that provide significant findings. Additionally, it is likely that a small number of unpublished articles may have been missed that led to publication bias, although extra steps were taken with limited success, to acquire unpublished studies. Another limitation related to the heterogeneity in reporting. Descriptions of HIT/HIS were often-times reported in insufficient detail, making it difficult to assess whether some system or technology capabilities were absent or simply not reported.

Conclusion and recommendations

This systematic review, based on 23 papers published between 1998 and 2008, has contributed to a better understanding of the relationship between the use of HIT/HIS and medical and health practices. It is noted that the number of studies assessing the impact of HIT/HIS on clinical practice has increased over the last few decades. However, only few studies to date have assessed the impact on patient outcomes. For example, in the current review only eight studies included patient outcomes as primary measures, and the results were inconsistent. It could be argued that this was mainly because of differences in the measured variables that yielded different effects from the interventions. For instance, studies that measured patient satisfaction from a particular care process during hospitalisation demonstrated positive effects, while others that assessed the patient outcomes from a medical stand point, such as recovery rate, demonstrated otherwise. Therefore, more studies are needed to warrant a stronger conclusion.

The current review also suggests several important future directions in this field. As the concept of quality assurance and quality management are taking central roles in the health care agenda, more studies that link HIT/HIS with business processes such as workflow redesign, organisational change, and project management, and with economic evaluation are needed, and additional funding for such works may be necessary. Furthermore, standardised reporting

of research on the implementation of HIT/HIS should also be introduced (similar to the existing standard for reporting trials and meta-analyses) to improve the quality of research used in decision-making in health care. Finally, findings from this study may provide useful information for the stakeholders interested in promoting or considering the adoption of HIT/HIS. Papers reviewed in this study could also inform stakeholders of effective ways to implement systems in order to maximise the value of investment, or how to direct policy aimed at increasing the uptake of evidence-based practice using HIT/HIS.

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Aziz Jamal BISM(Hons), BHSc
 Master of Health Science Candidate
 School of Public Health
 Queensland University of Technology
 Victoria Park Road
 Kelvin Grove QLD 4059
 AUSTRALIA
 email: azizabduls.jamal@gmail.com

Kirsten McKenzie BSSc(Hons)(Psych),MPHAA, PhD
 Research Fellow
 School of Public Health
 Queensland University of Technology
 Victoria Park Road
 Kelvin Grove QLD 4059
 AUSTRALIA
 Tel: +61 7 3138 9753
 Fax: 61 7 3138 5515
 email: k.mckenzie@qut.edu.au

Corresponding author:
Michele Clark BachOccThy(Hons), BA, PhD
 Professor
 School of Public Health
 Queensland University of Technology
 Victoria Park Road
 Kelvin Grove QLD 4059
 AUSTRALIA
 Tel: +61 7 3138 3525
 Fax: 61 7 3138 3369
 email: mj.clark@qut.edu.au