A review on systematic reviews of health information system studies

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ABSTRACT

The purpose of this review is to consolidate existing evidence from published systematic reviews on health information system (HIS) evaluation studies to inform HIS practice and research. Fifty reviews published during 1994–2008 were selected for meta-level synthesis. These reviews covered five areas: medication management, preventive care, health conditions, data quality, and care process/outcome. After reconciliation for duplicates, 1276 HIS studies were arrived at as the non-overlapping corpus. On the basis of a subset of 287 controlled HIS studies, there is some evidence for improved quality of care, but in varying degrees across topic areas. For instance, 31/43 (72%) controlled HIS studies had positive results using preventive care reminders, mostly through guideline adherence such as immunization and health screening. Key factors that influence HIS success included having in-house systems, developers as users, integrated decision support and benchmark practices, and addressing such contextual issues as provider knowledge and perception, incentives, and legislation/policy.

INTRODUCTION

The use of information technology to improve patient care continues to be a laudable goal in the health sector. Some argue we are near the tipping point where one can expect a steady rise in the number of health information systems (HISs) implemented and their intensity of use in different settings, especially by healthcare providers at point of contact.[1] A number of European nations are already considered leaders in the use of electronic medical records in primary care, where physicians have been using electronic medical records in their day-to-day practice for over a decade.[2] As for our current state of HIS knowledge, a 2005 review by Ammenwerth and de Keizer[3] has identified 1035 HIS field evaluation studies reported during 1982–2002. Over 100 systematic reviews have also been published to date on various HIS evaluation studies. Despite the impressive number of HIS studies and reviews available, the cumulative evidence on the effects of HIS on the quality of care continues to be mixed or even contradictory. For example, Han *et al*[4] reported an unexpected rise in mortality after their implementation of a computerized physician order entry (CPOE) system in a tertiary care children's hospital. Yet, Del Beccaro *et al*[5] found no association between increased mortality and their CPOE implementation in a pediatric intensive care unit. Even in a computerized hospital, Nebeker *et al*[6] found that high adverse drug event (ADE) rates persisted. However, as demonstrated by Ash *et al*,[7] CPOE effects can be unpredictable because of the complex interplay between the HIS, users, workflows, and settings involved. There is a need for higher level synthesis to reconcile and make sense of these HIS evaluation studies, especially those systematic review findings already published.

This review addresses the latter gap by conducting a meta-level synthesis to reconcile the HIS evidence base that exists at present. Our overall aim is to consolidate published systematic reviews on the effects of HIS on the quality of care. This will help to better inform HIS practice and research. In particular, this meta-level synthesis offers three contributions to practitioners and researchers involved with HIS implementation and evaluation. Firstly, it provides a comprehensive guide on the work performed to date, allowing one to build on existing evidence and avoid repetition. Secondly, by reconciling and reporting the systematic review findings in a consistent manner, we translate these synthesized reviews in ways that are relevant and meaningful to HIS practitioners. Lastly, the consolidated evidence provides a rational basis for our recommendations to improve HIS adoption and identify areas that require further research.

In this paper, we first describe the review method used. Then we report the review findings, emphasizing the meta-synthesis to make sense of the published systematic reviews found. Lastly, we discuss the knowledge and insights gained, and offer recommendations to guide HIS practice and research.

REVIEW METHOD

Research questions

This review is intended to address the current need for a higher level synthesis of existing systematic reviews on HIS evaluation studies to make sense of the findings. To do so, we focused on reconciling the published evidence and comparing the evaluation metrics and quality criteria of the multiple studies. Our specific research questions were: (1) What is the cumulative effect of HIS based on existing systematic reviews of HIS evaluation studies? (2) How was the quality of the HIS studies in these reviews determined? (3) What evaluation metrics were used in the HIS studies reviewed? (4) What recommendations can be made from this meta-synthesis to improve future HIS adoption efforts? (5) What are the research implications? Through this review, we aimed to synthesize the disparate HIS review literature published to date in ways that are rigorous, meaningful, and useful to HIS practitioners and researchers. At the same time,

by examining the quality of the HIS studies reviewed and the evaluation metrics used, we should be able to improve the rigor of planning, conduct, and critique of future HIS evaluation studies and reviews.

Review identification and selection

An extensive search of systematic review articles on HIS field evaluation studies was conducted by two researchers using Medline and Cochrane Database of Systematic Reviews covering 1966–2008. The search strategy combined terms in two broad themes of information systems and reviews: the former included information technology, computer system, and such MeSH headings as electronic patient record, decision support, and reminder system; the latter included systematic review, literature review, and review. The search was repeated by a medical librarian to ensure all known reviews had been identified. The reference sections of each article retrieved were scanned for additional reviews to be included. A hand search of key health informatics journals was carried out by the lead researcher, and known personal collections of review articles were included.

The inclusion criteria used in this review focused on published systematic reviews in English on HIS used by healthcare providers in different settings. The meaning of HIS was broadly defined on the basis of the categories of Ammenwerth and de Keizer[3] to cover different types of systems and tools for information processing, decision support, and management reporting, but excluded telemedicine/telehealth applications, digital devices, systems used by patients, and those for patient/provider education. The reason for such exclusion was that separate reviews were planned in these areas for subsequent publication. All citation screening and article selection were performed independently by two researchers and a second librarian. Discrepancies in the review process were resolved by consensus among the two researchers, and subsequently confirmed by the second librarian.

Meta-synthesis of the reviews

The meta-level synthesis involved reconciliation of key aspects of the systematic review articles through consensus by two researchers to make sense of the cumulative evidence. The meta-synthesis involved six steps: (1) the characteristics of each review were summarized by topic areas, care settings, HIS features, evaluation metrics, and key findings; (2) the assessment criteria used in the reviews to appraise the quality of HIS studies were compared; (3) the evaluation metrics used and the effects reported were categorized according to an existing HIS evaluation framework; (4) duplicate HIS studies from the reviews were reconciled to arrive at a non-overlapping corpus; (5) the aggregate effects of a subset of non-overlapping controlled HIS studies from selected topic areas were tabulated by HIS features and metrics already used as organizing schemes in the reviews; (6) factors identified in the reviews that influenced HIS success were consolidated and reported.

Specifically, the type and relationship of specific HIS features, metrics, and their effects on quality of care were summarized using the methods and outputs found in the existing HIS reviews. Five predefined topic areas for medication management, preventive care, health conditions, data quality, and care process/outcome were used. These topics were adapted from the organizing schemes used in the reviews by Balas *et al*,[8] Cramer *et al*,[9] and Garg *et al*[10] which covered multiple healthcare domains. The existing HIS evaluation framework used was the Canada Health Infoway Benefits Evaluation (BE) Framework already adopted in Canada.[11] This is similar to the approach used by van der Meijden *et al*[12] in categorizing a set of evaluation attributes from 33 clinical information systems according to the Information System (IS) Success model by DeLone and McLean[13] on which the Infoway BE Framework was based.

To identify the subset of controlled HIS studies and their effects, two researchers worked independently to retrieve the full articles for all original HIS studies within the corpus to extract the data on designs, metrics, and results. To aggregate HIS effects, the 'vote-counting' method applied in four reviews was used to tally the number of positive/neutral/negative studies based on significant differences between groups.[8 10 14 15] In studies with multiple measures, Garg's method was adopted where ≥50% of the results should be significant to be counted as positive.[10] To visualize the aggregate effects, Dorr's method was applied to plot the frequency of positive, neutral, and negative studies in stacked bar graphs.[14] The two researchers worked independently on the aggregate analysis and reconciled the outputs through consensus afterwards.

REVIEW FINDINGS

Synopsis of HIS reviews

Our initial library database and hand searches returned over 1200 citation titles/abstracts. By applying and refining the inclusion/exclusion criteria, we eventually identified 136 articles for further screening. Of these 136 articles, 58 were considered relevant and reviewed in detail. Of the 78 rejected articles, 23 were telehealth/telemedicine-related, 14 were patient-oriented systems, 11 were conceptual papers, seven had insufficient detail, seven involved other types of technologies, seven were not systematic reviews, five were on personal digital assistant devices, and four had HIS as only one of the interventions examined. Twenty-nine (50%) of the 58 selected review articles were published since 2005. Most had lead authors from the USA (22 (38%)) and UK (16 (28%)). The remaining reviews were from Canada (six (10%)), France (five (9%)), the Netherlands (four (7%)), Australia (three (5%)), Austria (one (2%)), and Belgium (one (2%)). Further examination of the 58 reviews showed that eight were updates or summaries of earlier publications. Hence, our final selection consisted of 50 review articles,[8–10 14–60] which included the eight updated/summary reviews instead of the original versions.[61–68] The review selection process is summarized in figure 1.

A synopsis of the 50 reviews by topic, author, care setting, study design, evaluation metric, and key findings is shown in table 1, available as an online data supplement at www.jamia.org. The HIS features in these reviews varied widely, ranging from the types of information systems and technologies used, the functional capabilities involved, to the intent of these systems. Examples are the review of administrative registers,[19] reminders,[27] and diabetes management,[32] respectively. A variety of care settings were reported, including academic/medical centers, hospitals, clinics, general practices, laboratories, and patient homes. Most of the studies were randomized controlled trials and quasi-experimental and observational studies, although some were qualitative or descriptive in nature.[18 30 56 59]

In terms of evaluation metrics and study findings, most reviews included tables to show the statistical measures and effects as reported in the original field studies. These measures and effects were mostly related to detecting significant between-group differences in guideline compliance/adherence, utilization rates, physiologic values, and surrogate/clinical outcomes. Examples include cancer screening rates,[38] clinic visit frequencies,[14] hemoglobin A1c levels,[32] lengths of stay,[54] adverse events,[40] and death rates.[55] Four reviews on data quality

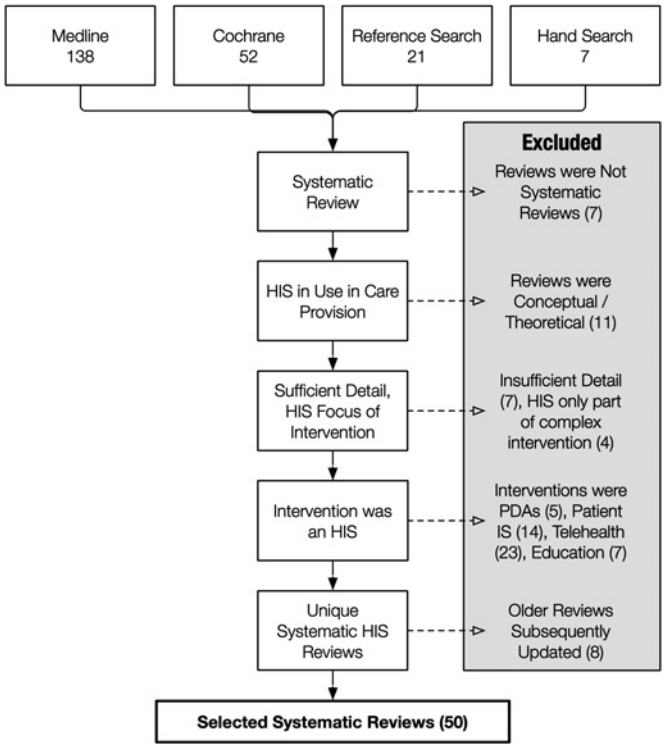

Figure 1 Review selection method. IS, information system; HIS, health information system; PDA, personal digital assistant.

reported predictive values and sensitivity/specificity rates.[19 35 39 56] Most of the reviews were narrative, with no pooling of the individual study results. Six reviews summarized their individual studies to provide aggregate assessment of whether the HIS had led to improvement in provider performance and patient outcome.[8 14 15 29 30 32] For instance, Garg *et al*[10] assigned a yes/no value to each HIS study depending on whether ≥50% of its evaluation metrics had significant differences. Only nine (18%) reviews included meta-analysis of aggregate effects.[9 21 24 27 28 32 42 51 55] The metrics used in these nine meta-analyses were odds/risk ratios and standardized mean differences with CIs shown as forest plots; eight included summary statistics to describe the aggregate effects, seven adjusted for heterogeneity (four fixed effect,[9 21 27 55] two random[28 32] and one mixed[51]), and three included funnel plots for publication bias.[9 42 51]

Assessment of methodological quality

Of the 50 reviews included in the synthesis, 31 (62%) mentioned they had conducted an assessment of the methodological quality of the HIS studies as part of their review. Of these 31 reviews, 20 included the individual quality rating of each HIS study in the article or via a website. For quality assessment instruments, there were 16 different variations of 14 existing quality scales and checklists reported, while eight others were created by review authors on an ad hoc basis. Thirteen of these 24 quality assessment instruments had items with numeric ratings that added up to an overall score, while the remaining 11 were in the form of checklists mostly with items for yes/no responses. Of the 14 existing instruments mentioned, the most common was the five-item scale from Johnston *et al*,[62] which was used in nine reviews.[17 10 15 41 43 48 61 63 65]

Further examination of the 24 instruments revealed three broad approaches. The first is based on the evidence-based medicine and Cochrane Review paradigm that assesses the quality of a HIS study design for potential selection, performance, attrition, and detection bias.[69] The second extends the assessment to include the reporting of such aspects as inclusion/exclusion criteria, power calculation, and main/secondary effect variables. The third is on HIS data/feature quality by comparing specific HIS features against some reference standards. An example of the first approach is the Johnston five-item scale with 0–2 points each based on the method of allocation to study groups, unit of allocation, baseline group differences, objectivity of outcome with blinding, and follow-up for analysis.[62] An example of the second is the 20-item scale by Balas *et al*[32] which includes the study site, sampling and size, randomization, intervention, blinding of patients/providers/measurements, main/secondary effects, ratio/timing of withdrawals, and analysis of primary/secondary variables. The third example is the Jaeschke *et al*[70] four-item checklist for data accuracy based on sample representativeness, independent/blind comparison against a reference standard not affected by test results, and reproducible method/results.

Types of evaluation metrics used

To make sense of the HIS evaluation metrics from the 50 reviews, we applied the Infoway BE Framework[11] as an organizing scheme from which we could categorize the measures in meaningful ways. The BE Framework explains how information, system, and service quality can affect the use of an HIS and user satisfaction, which in turn can influence the net benefits that are realized over time. In this framework, net benefits are measured under the dimensions of healthcare quality, provider productivity, and access to care. Measures that did not fit into the existing BE dimensions were grouped under new categories that we created on the basis of the types of measures and effects involved. A summary of the evaluation metrics from the 50 reviews under the BE Framework dimensions of system, information and service quality, HIS usage and satisfaction, and net benefits of care quality, productivity and access are shown in table 1. The additional categories of evaluation metrics identified in our meta-synthesis are shown in table 2.

In table 1, under the HIS quality dimensions, most of the evaluation metrics reported were on system function and information content. Examples of 'functionality' include evaluation of: CPOE with integrated, stand alone or no-decision support features[24 29]; commercial HIS compared with homegrown systems[22 24]; and the accuracy of decision support triggers such as medication alerts.[9 23] Examples of information 'content' metrics were related to the accuracy, completeness, and comprehension of electronic patient data collected.[19 20] Under the HIS use dimensions, most of the measures were on actual HIS use, provider satisfaction, and usability.[14 20 25] Under the net benefits dimensions, most of the measures were around 'care quality' and 'provider productivity.' For care quality, the most common measures in the 'patient safety' category were medical errors and reportable and drug dosing-related events.[20 22 24] In the 'appropriateness and effectiveness' category the most common measures were adherence/compliance to guidelines and protocols.[8 27] In the 'health outcomes' category the most common measures include mortality/morbidity, length of stay, and physiological and psychological measures.[8 60] For provider productivity, the most common measures in the 'efficiency' category were resource utilization and provider time spent, time-to-care and service turnaround time.[8 27 32] In the 'net cost' category, different types of healthcare costs, especially hospital and drug charges, were among the common measures.[8 32 45]

Table 2 shows the measures from the reviews that did not fit into the dimensions/categories under the BE Framework. The

Table 1 Mapping factors from HIS studies to the benefits evaluation framework

HIS quality	HIS use	Net benefits
SYSTEM QUALITY ► ***Functionality*—features, DS levels** – HIS±DS[15 24 29 30 33 40–42 50 53 54 59 60] – Commercial versus home grown[10 22 24 30] – HIS accuracy[9 23 29 30 33 34 42 59] ► ***Performance*—access, reliability, response time** – None ► ***Security*—features, levels of support** – Secure access[20]	USAGE ► ***Use behavior/pattern*—actual system use** – Actual HIS use[9 20 25 29 30 36 40–42 44 46 58] ► ***Self-reported use*—perceived system use** – Perceived improvement[29 58] ► ***Intention to use*—non-user proportion/ readiness** – None SATISFACTION ► ***Competency*—knowledge, skills, expertise** – Provider knowledge[44] ► ***User perception*—expectations, experiences** – Provider satisfaction[20 25 29 30 43 53] ► ***Ease of use*—user-friendliness, learnability** – Usability[14 25 29 30 53 57]	CARE QUALITY ► ***Patient safety*—AE, surveillance, risk reduction** – Medical errors/reportable events[16 20 22 24 29 30 33 35 40 46 49 52 54 60] – Drug dosing[9 10 15 21 22 28 30–32 40 43 48 49 52 54 55] ► ***Appropriateness and effectiveness*—guidelines, care continuity, practice standards** – Adherence/compliance[8–10 14–18 20 22 25–27 29 30 32 33 37 38 41 43 44 49 51 53 54 58] ► ***Health outcomes*—surrogate, clinical, status** – Mortality/morbidity/LOS[13 14 20 21 23 25 27 28 30 32 33 37 46 48 49 52 54 55 57] – Physio/psychological measures[8–10 14 17 20 21 32 36 43 44 48–50 53–55] – Quality of life[32 9 14 36] PRODUCTIVITY ► ***Efficiency*—utilization, outputs, capacity** – Resource utilization[8–10 14–18 20–22 25 27 29 30 32 33 36 37 41–44 47–49 52–54 57 58] – Provider time[20 22 25 29 30 32 33 37 43 46–48 57 58] – Time-to-care/turnaround[10 22 23 33 48 49 53 58] ► ***Care coordination*—continuity, team care** – Communication[33 58] ► ***Net cost*—avoidance, reduction, savings** – Healthcare cost[8 9 14 16–18 20 22 23 29 30 33 36 43 46 47 49 52 53 58] ACCESS ► ***Access*—service availability/accessibility, patient and provider participation, self-care** – Availability/accessibility (None) – Participation/self-care communication[25] – Patient-initiated/self-care[8 16 17 20 32]

AE, adverse event; DS, decision support; HIS, health information system; LOS, lenth of stay.

most common measures were related to 'patients/providers', such as their knowledge, attitude, perception, compliance, decision confidence, overall satisfaction, and relationships.[9 36 43] Another group of measures were 'implementation' related including barriers, training, organizational support, project management, leadership and cost.[20 25 32 40] Others were related to 'legislation/policy', such as mandate and confidentiality,[20 58] as well as the correlation between HIS features with extent of changes and intended effects.[14 15]

Finally, we created a visual diagram in figure 2 to show the frequency distribution of HIS studies for the evaluation dimensions/categories examined in the reviews. From this figure one can see that efficiency, health outcomes, and patient safety are the three categories with the most HIS studies reported. Conversely, there is little to no study for such categories as care coordination, user competency, information availability, and service quality.

Non-overlapping review corpus

The 50 reviews in our meta-synthesis covered 2122 HIS studies. However, many of these studies were duplicates, as they appeared in more than one review. For instance, the 1999 CPOE study by Bates *et al*[71] was appraised in seven different reviews.[22 24 30 40 46 49 60] The 50 reviews covered the topics of medication management, preventive care, health conditions, and data quality, plus an assortment of care process/management. There were multiple reviews published in each of these five areas, and they all had overlapping HIS studies. For example, there were 13 reviews with 275 HIS studies on medication management. But only 206 of these studies were unique, as the remaining 69 were duplicates. Some studies were reviewed differently, not only from a methodological standpoint, but also in the indicators examined. Four of the reviews under care process/outcome each contained 100 or more HIS studies in multiple domains.[10 15 20 22] Yet, many of these studies were also contained in the reviews under the four other topic areas mentioned. For instance, the review by Garg *et al*[10] on clinical decision support systems (CDSS) had 100 HIS studies covering the domains of diagnosis, prevention, disease management, drug dosing, and prescribing. However, only eight (8%) were unique studies[72–79] that had not already appeared in the other reviews.

As part of our meta-synthesis, we reconciled the 50 reviews to eliminate duplicate HIS studies to arrive at a non-overlapping corpus. When the HIS studies appeared in multiple reviews, we included them just once in the most recent review under a specific topic where possible. After the reconciliation, we arrived at 1276 non-overlapping HIS studies. Next we took the 30 reviews under the four topic areas of medication management, preventive care, health conditions, and data quality to examine the HIS and effects reported. The 20 reviews under care process/outcome were not included as they were too diverse for meaningful categorization and comparison. Upon closer examination, we found that over half of the 709 non-overlapping HIS studies in these 30 reviews contained descriptive results, insufficient detail, no control groups, patient/paper systems or special devices, which made it infeasible to tabulate the effects. For example, we eliminated 24 of the 67 HIS studies in the review of Eslami *et al*[30] as they had no controls or insufficient detail for comparison. After this reconciliation, we reduced the 709 non-overlapping HIS studies to 287 controlled HIS studies for the 30 reviews under the four topic areas.

Associating HIS features, metrics with effects

The cumulative effects by HIS features from the 30 reviews for the four topic areas are shown in table 3 and summarized in figure 3A. In table 3, the overall ratio of positive controlled HIS studies is 180/287 (62.7%). The most effective HIS features were computer-based reminder systems in preventive care (100%), CDSS reminders/alerts in medication management (80%), and disease

Table 2 Additional measures not found in the benefits evaluation framework

Category	HIS evaluation metrics	Review reference sources
Patient/provider	Patient knowledge, attitude, perception, decision confidence, compliance	8 9 32 36 43 44 53 57
	Patient/provider overall satisfaction	20 25 32 36 43 53 58
	Patient/provider knowledge acquisition, relationship	9 25 43 57
	Provider attitude, perceptions, autonomy, experience and performance	10 25 43 57
	Workflow	14 20 30
Incentives	Reimbursement mix, degree of capitation	22 40
Implementation	Barriers, training, organizational support, time-to-evaluation, lessons, success factors, project management, leadership, costs	14 20 22 25 40 43 45 49
Legislation/policy	Privacy, security, legislations, mandates, confidentiality	14 20 25 40 43 58
Correlation	Correlation of HIS feature/use with change in process, outcome, success	14 15 49 54
Change/ improvement	Data quality improvement, reduced loss/paper and transcription errors, DS improvement	35 57 59
Interoperability	Information exchange and interoperability, standards	20

DS, decision support.

management-orders/alerts in health conditions (80%). The HIS features that were somewhat effective included CPOE medication orders (66.1%), reminders in printed form (69.6%), and reminders combined with other interventions (66.7%). Facility-based electronic patient record (EPR) systems and administrative registers/research databases had better data quality than primary-care EPR systems (76.2% and 70.4% vs 58.3%). Note that 98/287 (34.1%) of these controlled HIS studies reported no significant effects, mostly in the area of disease management where 30/57 (52.6%) had neutral findings.

Next, the cumulative effects by evaluation measures from the 30 reviews for the four topic areas are shown in table 4 and summarized in Figure 3B. In total, 575 evaluation measures were reported in the 287 controlled HIS studies. Table 4 shows that the overall ratio of HIS metrics with positive effects is 313/575 (54.4%). The HIS metrics with positive effects are mostly under the dimension of care quality in patient safety for medication errors (63.6%), and in guideline adherence for immunization (84.6%), health screening (66.7%), tests/assessments/care (64.4%), and medications (61.8%). Under information quality, 76.4% of HIS metrics had positive effects in content accuracy, and 61.0% were positive in completeness. Note that 244/575 (42.4%) of HIS metrics showed no significant effects, mostly in the areas of health outcomes, adverse event detection, and resource utilization.

Summary of key findings

The 'take-home message' from this review is that there is some evidence for improved quality of care, but in varying degrees across topic areas. For instance, HIS with CPOE and CDSS were effective in reducing medication errors, but not those for drug dosing in maintaining therapeutic target ranges or ADE monitoring because of high signal-to-noise ratios. Reminders were effective mostly through preventive care guideline adherence. The quality of electronic patient data was generally accurate and complete. Areas where HIS did not lead to significant improvement included resource utilization, healthcare cost, and health outcomes. However, in many instances, the studies were not designed nor had sufficient power/duration to properly assess health outcomes. For provider time efficiency, four of 12 studies reported negative effect where HIS required more time and effort to complete the tasks. Caution is needed when interpreting these findings, because there were wide variations in organizational contexts and how the HIS were designed/implemented, used, and perceived. In some cases, the HIS was only part of a complex set

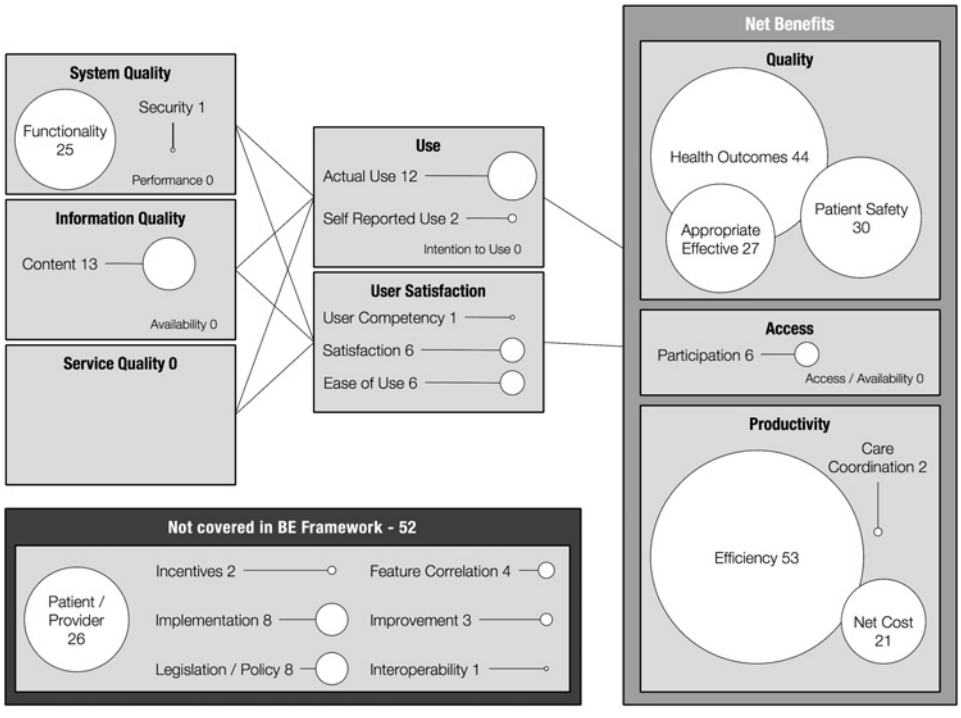

Figure 2 Distribution of health information system studies by evaluation dimensions/categories.

Table 3 Frequency of positive, neutral, and negative controlled health information system (HIS) studies by reported HIS features

HIS features	Positive (%)	Neutral (%)	Negative (%)	Total
Medication management				
CPOE medication orders	41 (66.1)	17 (27.4)	4 (6.5)	62
CDSS reminders/alerts/feedback	12 (80.0)	3 (20.0)	0 (0.0)	15
Drug dosing/prescribing	11 (52.4)	10 (47.6)	0 (0.0)	21
Adverse drug event monitoring	2 (40.0)	3 (60.0)	0 (0.0)	5
Subtotal	66 (64.1)	33 (32.0)	4 (3.9)	103
Preventive care				
Reminders—computer	5 (100.0)	0 (0.0)	0 (0.0)	5
Reminders—printed	16 (69.6)	7 (30.4)	0 (0.0)	23
Reminders+other interventions—printed	10 (66.7)	5 (33.3)	0 (0.0)	15
Subtotal	31 (72.1)	12 (27.9)	0 (0.0)	43
Health conditions				
Diagnostic aid—abdominal/chest pain	2 (28.6)	5 (71.4)	0 (0.0)	7
Disease management—diabetes	7 (50.0)	7 (50.0)	0 (0.0)	14
Disease management—hypertension	7 (58.3)	5 (41.7)	0 (0.0)	12
Disease management—other conditions	7 (36.8)	12 (63.2)	0 (0.0)	19
Disease management—orders/alerts	4 (80.0)	1 (20.0)	0 (0.0)	5
Subtotal	27 (47.4)	30 (52.6)	0 (0.0)	57
Data quality				
EPR in primary care	21 (58.3)	12 (33.3)	3 (8.3)	36
Facility-based EPR	16 (76.2)	3 (14.3)	2 (9.5)	21
Admin registers/research databases	19 (70.4)	8 (29.6)	0 (0.0)	27
Subtotal	56 (66.7)	23 (27.4)	5 (6.0)	84
Total	180 (62.7)	98 (34.1)	9 (3.1)	287

Values are number (%).
CDSS, clinical decision support systems; CPOE, computerized physician order entry; EPR, electronic patient record.

of interventions that included changes in clinical workflow, provider behavior, and scope of practice.

DISCUSSION

Cumulative evidence on HIS studies

This review extends the HIS evidence base in three significant ways. Firstly, our synopsis of the 50 HIS reviews provide a critical assessment of the current state of knowledge on the effects of HIS in medication management, health conditions, preventive care, data quality, and care process/outcome. Our concise summary of the selected reviews in supplementary online table 1 can guide HIS practitioners in planning/conducting HIS evaluation studies by drawing on approaches used by others and comparing their results with what is already known in such areas as electronic prescribing,[24] drug dosing,[28] preventive care reminders,[26] and EPR quality.[56]

Secondly, the grouping of evaluation metrics from the 50 HIS reviews according to the Infoway BE Framework (which is based on DeLone's IS Success Model[13]) provides a coherent scheme when implementing HIS to make sense of the different factors that influence HIS success. Through this review, we also found additional factors not covered by the BE Framework that warrant its further refinement (refer to table 2). These factors include having in-house systems, developers as users, integrated decision support, and benchmark practices. Important contextual factors include: patient/provider knowledge, perception and attitude; implementation; improvement; incentives; legislation/policy; and interoperability.

Thirdly and most importantly, our meta-synthesis produced a non-overlapping corpus of 1276 HIS studies from the 50 reviews and consolidated the cumulative HIS effects in four healthcare domains with a subset of 287 controlled studies. This is a significant milestone that has not been attempted previously. To illustrate, many of the 50 reviews were found subsumed by the more recent Garg *et al*,[10] Nies *et al*,[15] Chaudhry *et al*,[22] and Car *et al*[20] reviews which cover 100, 106, 257, and 284 HIS studies in multiple domains, respectively. Yet with these four comprehensive reviews, it was difficult to integrate their findings in a meaningful way because of significant overlapping of the HIS studies. The findings were also reported in different forms, making comparison even more challenging. In contrast, our organizing scheme for associating HIS features, metrics, and effects using a non-overlapping corpus as shown in Figure 3A, B provide a concise and quantifiable way of consolidating review findings that is relevant and meaningful to HIS practitioners.

Recommendations to improve HIS adoption

We believe the cumulative evidence from this meta-synthesis provides the contexts needed to guide future HIS adoption efforts. For example, our consolidated findings suggest there is evidence of improved quality in preventive care reminders and CPOE/CDSS for medication management. As such, one may focus on replicating successful HIS adoption efforts from benchmark institutions such as those described in the Dexheimer *et al*[26] and Ammenwerth *et al*[24] reviews for reminders and e-prescribing, respectively, by incorporating similar HIS features and practices into the local settings. Conversely, in drug dosing, ADE monitoring, and disease management, where the evidence from our synthesis is variable, attention may shift to redesigning HIS features/workflows and addressing contextual barriers that have hindered adoption, as described in the van der Sijs *et al*,[59] Bates *et al*[45] and Dorr *et al*[14] reviews. The distribution of HIS studies by evaluation dimension from our meta-synthesis (refer to figure 2) shows that the areas requiring ongoing research attention are HIS technical performance, information availability, service quality, user readiness (intention to use HIS), user competency, care access/availability, and care coordination. In particular, the shift toward team-based care, as shown in the review of van der Kam *et al*,[58] will require the careful implementation of HIS to facilitate effective communication and information sharing across the care continuum, which is not well addressed at present.[80] Given the importance of contexts in HIS adoption as suggested in the Chaudhry *et al*[22] and Car *et al*[20] reviews, practitioners and researchers should refer to specific HIS studies in the corpus that are similar to their organizational settings and practices for comparison and guidance.

Drawing on this cumulative evidence, we have three recommendations to improve HIS adoption. Firstly, to emulate successful HIS benchmark practices, one must pay attention to specific HIS features and key factors that are critical to 'making the system workable.' To do so, frontline healthcare providers must be engaged on an ongoing basis to ensure the HIS can be integrated into the day-to-day work practice to improve their overall performance. The HIS must be sufficiently adaptable over time as providers gain experience and insights on how best to use more advanced HIS features such as CDSS and reminders. Secondly, there should be a planned and coordinated approach to 'addressing the contextual issues.' The metrics identified as extensions to the Infoway BE Framework on patients/providers, incentives, change management, implementation, legislation/policy, interoperability, and correlation of HIS features/effects are all issues that must be addressed as needed. Thirdly, one has to demonstrate return-on-value by 'measuring the clinical impact.' Evaluation should be an integral part of all HIS adoption efforts in healthcare organizations. Depending on the stage

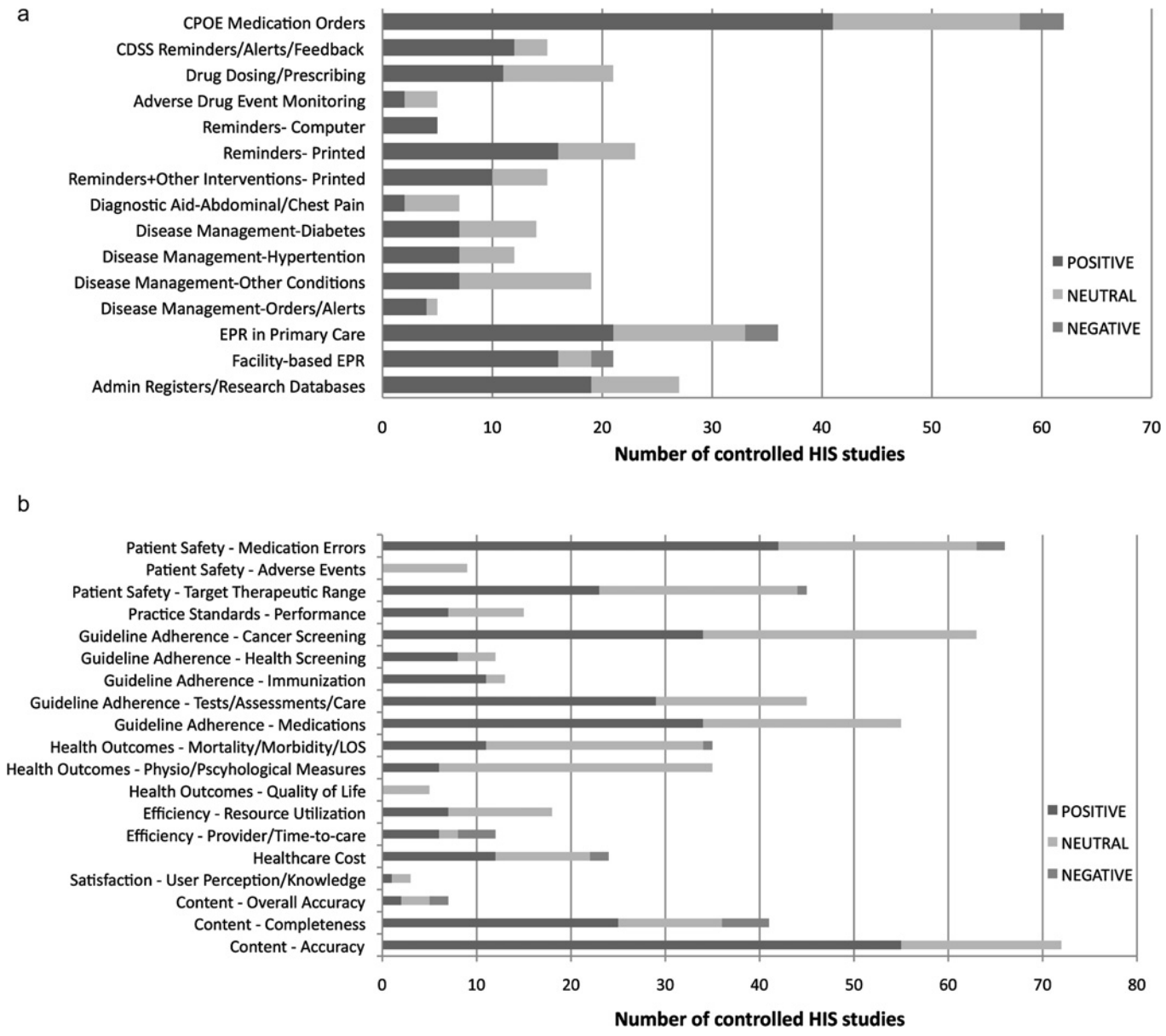

Figure 3 (A) Frequency of positive, neutral and negative controlled health information system (HIS) studies by reported HIS features. (B) Frequency of positive, neutral, and negative controlled HIS studies by reported HIS metrics. CDSS, clinical decision support systems; CPOE, computerized physician order entry; EPR, electronic patient record; LOS, length of stay.

of HIS adoption, appropriate evaluation design and metrics should be used to examine the contexts, quality, use, and effects of the HIS involved. For example, organizations in the process of implementing an HIS should conduct formative evaluation studies to ensure HIS—practice fit and sustained use through ongoing feedback and adaptation of the system and contexts. When a HIS is already in routine use, summative evaluation with controlled studies and performance/outcome-oriented metrics should be used to determine the impact of HIS usage. Qualitative methods should be included to examine subjective effects such as provider/patient perceptions and unintended consequences that may have emerged.

Implications for HIS research

Given the amount of evidence already in existence, it is important to build on such knowledge without duplicating effort. Researchers interested in conducting reviews on the effects of specific HIS could benefit from our review corpus by leveraging what has already been reported to avoid repetition. Those wishing to conduct HIS evaluation studies could consider our organizing schemes for categorizing HIS features, metrics, and effects to improve their consistency and comparability across studies. The variable findings across individual studies evaluating equivalent HIS features suggest that further research is needed to understand how these systems should be designed. Even having HIS features such as CDSS in medication management with strong evidence does not guarantee success, and indeed, may cause harm.[81] Research into the characteristics of success using such methods as participatory design,[82] usability engineering,[83] and project risk assessment[84] will be critical to planning and guiding practitioners in successful implementations. Also, further research into the nature of system design, as suggested in the Kawamoto *et al*[41] review (eg, usability, user experience, and contextualized process analysis), could help to promote safer and more effective HIS design.

Table 4 Frequency of positive, neutral and negative controlled health information system (HIS) studies by reported HIS metrics

HIS metrics	Positive (%)	Neutral (%)	Negative (%)	Total
Care quality				
Patient safety—medication errors	42 (63.6)	21 (31.8)	3 (4.5)	66
Patient safety—adverse events	0 (0.0)	9 (100.0)	0 (0.0)	9
Patient safety—target therapeutic ranges	23 (51.1)	21 (46.7)	1 (2.2)	45
Practice standards—provider performance	7 (46.7)	8 (53.3%)	0 (0.0)	15
Guideline adherence—cancer screening	34 (54.0)	29 (46.0)	0 (0.0)	63
Guideline adherence—health screening	8 (66.7)	4 (33.3)	0 (0.0)	12
Guideline adherence—immunization	11 (84.6)	2 (15.4)	0 (0.0)	13
Guideline adherence—tests/assessments/care	29 (64.4)	16 (35.6)	0 (0.0)	45
Guideline adherence—medications	34 (61.8)	21 (38.2)	0 (0.0)	55
Health outcomes—mortality/morbidity/LOS	11 (31.4)	23 (65.7)	1 (2.9)	35
Health outcomes—physio/psychological measures	6 (17.1)	29 (82.9)	0 (0.0)	35
Health outcomes—quality of life	0 (0.0)	5 (100.0)	0 (0.0)	5
Subtotal	205 (51.5)	188 (47.2)	5 (1.3)	398
Provider productivity				
Efficiency—resource utilization	7 (38.9)	11 (61.1)	0 (0.0)	18
Efficiency—provider time/time-to-care	6 (50.0)	2 (16.7)	4 (33.3)	12
Healthcare cost	12 (50.0)	10 (41.7)	2 (8.3)	24
Subtotal	25 (46.3)	23 (42.6)	6 (11.1)	54
User satisfaction				
User perception—experiences, knowledge	1 (33.3)	2 (66.7)	0 (0.0)	3
Information quality				
Content—accuracy	55 (76.4)	17 (23.6)	0 (0.0)	72
Content—completeness	25 (61.0)	11 (26.8)	5 (12.2)	41
Content—overall quality	2 (28.6)	3 (42.9)	2 (28.6)	7
Subtotal	82 (68.3)	31 (25.8)	7 (5.8)	120
Total	313 (54.4)	244 (42.4)	18 (3.1)	575

LOS, length of stay.

This meta-synthesis has shown that different methodological quality assessment instruments were applied in the reviews. There was considerable variability across reviews when the same studies were assessed. These instruments need to be streamlined to provide a consistent approach to appraising the quality of HIS studies. For example, the Johnston *et al*[62] five-item quality scale could be adopted as the common instrument, as it is already used in 10 reviews. The analysis and reporting of HIS evaluation findings in the reviews also require work. The current narrative approach to summarizing evaluation findings lacks a concise synthesis for HIS practitioners, yet more sophisticated techniques such as meta-analysis are not easy to comprehend. Further work is needed on how one can organize review findings in meaningful ways to inform HIS practice.

Review limitations

There are limitations to this meta-synthesis. Firstly, only English review articles in scientific journals were included; we could have missed reviews in other languages and those in gray literature. Secondly, we excluded reviews in telemedicine/telehealth, patient systems, education interventions, and mobile devices; their inclusion may have led to different interpretations. Thirdly, our organizing schemes and vote-counting methods for correlating HIS features, metrics, and effects were simplistic, which may not have reflected the intricacies associated with specific HIS and evaluation findings reported. Lastly, our meta-analysis covered a wide range of complex issues, and could be viewed as ambitious and inadequate for addressing them in a substantive manner.

CONCLUSIONS

This meta-synthesis shows there is some evidence for improved quality of care from HIS adoption. However, the strength of this evidence varies by topic, HIS feature, setting, and evaluation metric. While some areas, such as the use of reminders for guideline adherence in preventive care, were effective, others, notably in disease management and provider productivity, showed no significant improvement. Factors that influence HIS success include having in-house systems, developers as users, integrated decision support and benchmark practices, and addressing such contextual issues as provider knowledge and perception, incentives, and legislation/policy. Drawing on this evidence to establish benchmark practices, especially in non-academic settings, is an important step towards advancing HIS knowledge.

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