

Leveraging Information Technology to Improve Quality and Safety

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Summary

Objectives: To examine five areas that will be central to informatics research in the years to come: changing provider behavior and improving outcomes, secondary uses of clinical data, using health information technology to improve patient safety, personal health records, and clinical data exchange.

Methods: Potential articles were identified through Medline and Internet searches and were selected for inclusion in this review by the authors.

Results: We review highlights from the literature in these areas over the past year, drawing attention to key points and opportunities for future work.

Conclusions: Informatics may be a key tool for helping to improve patient care quality, safety, and efficiency. However, questions remain about how best to use existing technologies, deploy new ones, and to evaluate the effects. A great deal of research has been done on changing provider behavior, but most work to date has shown that process benefits are easier to achieve than outcomes benefits, especially for chronic diseases. Use of secondary data (data warehouses and disease registries) has enormous potential, though published research is scarce. It is now clear in most nations that one of the key tools for improving patient safety will be information technology—many more studies of different approaches are needed in this area. Finally, both personal health records and clinical data exchange appear to be potentially transformative developments, but much of the published research to date on these topics appears to be taking place in the U.S.—more research from other nations is needed.

Keywords

Physicians' practice patterns, patient safety, registries, personal health records, regional health information organizations

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Introduction and Background

Healthcare practitioners and organizations are striving to improve quality of care and patient outcomes and to make care safer, while reducing costs and increasing efficiency. Put another way, the challenge is to make sure patients reliably receive the care they are supposed to, in a safe, efficient, and cost-effective manner. However, evidence demonstrates that many patients do not receive recommended care. In 2003, McGlynn and colleagues surveyed adults in the United States and reviewed their medical records to assess 439 indicators of quality of care for 30 acute and chronic conditions, as well as preventive care [1]. They found that participants received only 54.9% of recommended care. Informatics is seen by many as a key tool for addressing this challenge.

Nonetheless, the evidence to date about this is mixed. A recent systematic review by Chaudhry and colleagues examined the evidence that health information technology (HIT) may affect quality, efficiency, and costs of care [2]. Reviewing 257 studies, most of which addressed decision support systems or electronic health records, they observed documented benefits for increased adherence to guidelines, enhanced surveillance and monitoring, and decreased medication errors. Efficiency and cost effects received less attention overall,

and showed mixed results. The authors noted that a large percentage (25%) of the studies were carried out at four academic medical centers in the United States. This raises the question of generalizability to other institutions and practice settings, although the extent to which this represents a real issue has been questioned [3]. In 2005, Garg and colleagues reviewed controlled trials to assess the effects of computerized decision support systems, finding that 64% of the studies showed improvement in practitioner performance [4]. However, they noted that effects on patient outcomes remain understudied. In general, over the past few years, there have been a number of published negative studies of informatics interventions, as well as studies showing positive but modest effects. The net result is that questions remain about how best to use existing technologies, deploy new ones, and to evaluate the effects, as well as how applicable results from academic, tertiary care medical centers are to other practice settings.

In this article, we will examine five areas, reviewing some highlights from the literature from the past year. The areas, which were chosen because of relevance to healthcare management and quality and because of our interest, are as follows:

- Changing provider behavior and improving outcomes
- Secondary uses of clinical data –

data warehousing, quality reporting, and disease registries

- Patient safety
- Personal health records
- Clinical data exchange and Regional Health Information Organizations

Changing Behavior and Improving Outcomes

Clinical decision support has been very effective in specific domains for improving performance on process measures, for example for preventive care [5] and for drug-related decision support [6]. However, with some exceptions, decision support has been less effective for improving process measure performance for chronic diseases [7]. It has been very hard to improve even intermediate outcome measures relative to process measures [8]. Specific research frontiers include 1) improving performance in chronic disease management using information technology as a component of a broader portfolio of performance improvement and 2) identifying new areas in which decision support can be helpful. Several important studies have added to knowledge in these areas in the last year.

Shojania et al performed a very interesting meta-regression, in which they compared the impact of 11 distinct strategies for quality improvement on adults with Type II diabetes, several of which involved health information technology [9]. However, only two of the 11 categories of strategies resulted in significant reduction in hemoglobin A1c levels: team changes and case management (Figure 1). Notably, interventions in which nurses or pharmacists could make regimen changes without waiting for physician authorization resulted in more improvement. Electronic patient registries and most clinician reminders involved health information

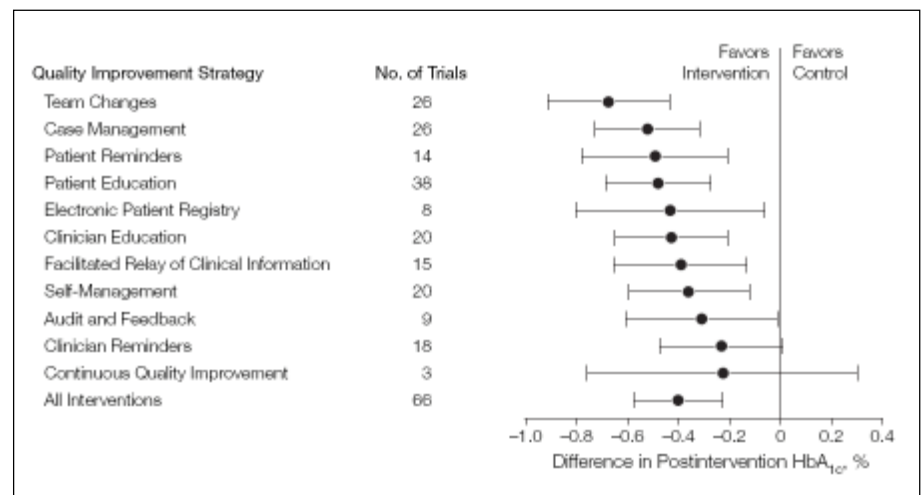


Fig. 1 Categories of improvement strategies and resulting reduction in Hemoglobin A1c levels. From: Shojania et al. Effects of quality improvement strategies for type 2 diabetes on glycemic control: a meta-regression analysis. *JAMA* 2006;296(4):427-440.

technology (although this was not explicitly presented), but had only modest effects. The authors also noted that single-strategy interventions had comparable effects to multifaceted interventions, although only a small number of single-strategy interventions were included. Moreover, use of health information technology may potentially enable and decrease the cost of virtually all types of interventions, including team changes and case management. In another study assessing the impact of disease management, Mangione et al evaluated the association between quality of care and the intensity of diabetes management programs [10]. In that study, reminders were associated with an increased rate of nephropathy screening. However, no strategies were associated with intermediate outcome levels or level of medication management.

A trial with positive results in a difficult domain—dementia detection—came from Downs et al in the United Kingdom [11]. They evaluated the effectiveness of education interventions for improving detection rates and management of dementia in primary care; all providers were using electronic records. Of 36 practices, eight were

randomized to receive decision support software. The decision support software and workshops both significantly improved rates of detection compared with controls. Of note, providers in the UK in primary care have generally been using electronic records for some time. In a study in the U.S., Palen et al evaluated the impact of computerized decision support on the medication error rate in primary care [12]. They asked whether reminders presented during CPOE for medications improved compliance for laboratory monitoring. They found, however, that there was no difference overall between the intervention and control groups in monitoring (56.6% intervention, 57.1% control). They did find a modest benefit for one specific drug, gemfibrozil.

In another study from the U.S., McGregor et al evaluated the impact of a computerized clinical decision support system for assisting their antimicrobial management team [13]. They found in a controlled trial that their antimicrobial team intervened in twice as many patients in the intervention group (16%) as the control group (8%), yet spent an hour less per day in the intervention arm. The net savings were

\$84,000, or \$38 per patient. No differences in mortality or length of stay were present. They concluded that this intervention could reduce costs and facilitate the work of the antimicrobial team.

Another multi-center study from Italy evaluated a long-standing problem, the likelihood of coronary-related chest pain of patients in the emergency room with chest pain [14]. The authors used a computerized protocol to stratify patients in with four subgroups of probability of coronary chest pain. Low-probability patients were discharged; high-probability patients were admitted to the coronary care unit. The incidence of coronary events in the four groups with increasing risk was 1.9%, 12.8%, 13.5% and 68%, respectively. The authors concluded that their protocol could be reliably used to stratify patients according to risk of coronary chest pain.

Secondary Uses of Clinical Data

Carefully designed and implemented clinical decision support (e.g. alerts and reminders), electronic health records, and computerized order entry systems may improve quality, but these methods tend to affect one patient at a time and focus on the office visit or inpatient admission. Complementing these approaches, the secondary use of clinical data—including structured documentation, unstructured narrative, laboratory results, and administrative data—may help drive measurement, improve quality, and help manage populations of patients, even when they are not face-to-face with a provider. The technologies for the secondary use of clinical data include data warehousing and disease registries. Interestingly,

the phrase “data warehouse” does not correspond to a Medical Subject Heading (MeSH) term. To prepare this review, literature searches were carried out using related subject headings like “databases” and uncoded strings like “data warehouse.” Relatively few references were identified—there are not many publications about healthcare data warehousing. Despite the paucity of published literature and lack of a MeSH term, there is increasing interest in data warehousing in healthcare. The Healthcare Data Warehousing Association (HDWA) now includes members representing 76 institutions—as of this writing, all were from the United States and Canada [15].

In data warehousing, the key idea is to externalize clinical and administrative transaction data in a retrospective database, which is optimized to support aggregate analyses and reports. Users make use of the data in a variety of ways such as ad hoc queries or predefined reports. In a paper in the *Journal of Medical Systems*, Wan describes how data warehouses can be used for exploratory analysis, data mining, statistical analysis, and simulation [16]. Dewitt describes the multi-year project to build an enterprise data warehouse at the University of Michigan—this paper highlights the attention paid to constructing the warehouse in a way that fit a decentralized health system where business drivers and priorities were not always clear [17]. Like any development or implementation project, successful implementation of a data warehouse requires careful attention to people and organizational issues. A data warehouse at Sherbrooke University Hospital is described by Grant and colleagues [18]. Data from the hospital information system has been externalized in a database that users access through a dashboard and through a query tool. Data is encrypted to pro-

vide security. Dashboards are used to provide feedback for two domains: emergency department occupancy and quality assurance evolution in the biochemistry department.

Several publications in the past year have examined the suitability of using electronic health record (EHR) data for quality measurement. This work may inform designers of EHRs and data warehouses about the extent to which quality measurement may be automated. For example, Persell and colleagues performed a validation study to assess how well EHR data could be used to produce ambulatory coronary artery disease measures, comparing structured EHR data (automated measurement) with unstructured narrative [19]. Performance varied widely; for example, automated assessment of lipid measurement was 81.6% accurate, increasing to 87.5% when augmented with manual review of free-text notes. They concluded that there are limitations to the automated assessment of outpatient CAD measures and that changes are needed in how data is recorded. Two studies published in 2006 by Brown and Turchin apply natural language processing techniques to unstructured narrative to extract specific findings or measures [20,21]. Brown focused on automated concept-based indexing to get quality measures for disability examinations, achieving sensitivity of 87% and specificity of 71%. Turchin used regular expressions to identify clinical data relevant to the management of hypertension, achieving sensitivity and specificity of 98% for identifying elevated blood pressure (precision 93%) and sensitivity of 84%, specificity 95%, and precision 86% for identifying hypertensive treatment intensification. Taken together, these studies illustrate the potential of the EHR for quality measurement, but also highlight the necessity and challenge of

dealing with unstructured narrative to achieve high levels of performance.

Registries represent another type of secondary use of clinical data—a database organized around a particular condition that is generally used to assess quality of care and to manage populations of patients. They are almost universally felt to be an important technology to drive improvement, but few studies have demonstrated measurable effects on patient outcomes. Over the past year, publications have illustrated many of the various ways that registries may be employed. One of the more novel examples is the requirement by New York City that hemoglobin A1c levels be reported and then gathered into a database (registry) that will be used to create public health interventions [22,23]. More traditional uses of registries to manage chronic conditions are described by Clark (coronary heart disease registers in the UK) and Georgiou (diabetes registries for general practitioners in Australia) [24,25]. These studies note the potential of disease registries, but did not formally evaluate their effect on patient outcomes. Finally, registries are increasingly employed both by insurers and healthcare institutions to assess and manage pay-for-performance contracts. Levin-Scherz and colleagues at Partners Community Health Care describe the use of a claims-based registry to track progress and help achieve pay-for-performance targets [26].

Patient Safety

Studies continue to assess the impact of health information technology on patient safety, and a number of new positive results have been reported. However, there has also been increasing attention to the unintended consequences of computerization, which makes sense, as any new technology can

have adverse and unintended consequences, especially early after implementation. A specific area which has received substantial recent attention has been medication safety, including medication reconciliation; the impact of computerizing prescribing, with evaluation of computerization using different modalities such as handhelds; and also the marginal impact of decision support for specific populations such as the elderly.

A study by Han et al published in 2005 in *Pediatrics* [27] reported a 3.3-fold increased risk of death in children in a pediatric intensive care unit transferred in for care after the implementation of a widely used commercial computerized physician order entry application at the University of Pittsburgh. This study has generated a great deal of controversy and commentary. In particular, the initial study did not use a strong study design, the institution appeared to ignore many of the rules for safe implementation of a computerized physician order entry application, and there may have been uncontrolled confounding [28].

In 2006, Del Beccaro et al assessed the impact on risk-adjusted mortality rate after implementation of computerized physician order entry in their pediatric intensive care unit at the University of Washington [29]. They found a reduction in the standardized mortality ratio of 36% for all patients in their ICU, although this difference was not statistically significant. Notably, their implementation process was substantially different than that at Pittsburgh.

These and other issues were explored in commentaries about these two apparently contradictory reports, in a paper by Ammenwerth et al [30]. Key conclusions were the importance of sociotechnical factors that influence the introduction of sophisticated systems in complex organizations, and the impor-

tance of developing guidelines for implementation of systems. In addition, well-trained health informaticians will be increasingly needed to guide and manage these implementation processes.

In another study with important patient safety implications, Poon et al [31] presented the design of a novel application that is aimed at assisting providers with medication reconciliation at admission and discharge. The application is designed to make it easy for the provider to review the patient's outpatient list at admission, carry over the appropriate medications, and flag any medications that are being discontinued but may be needed later, at discharge, with the reverse of this approach at discharge. Although medication reconciliation has been made a requirement by the Joint Commission on Accreditation of Hospitals, hospitals throughout the U.S. have struggled with implementing the requirement, as it is highly labor-intensive, taking approximately 30 minutes for reconciliation on average based on anecdotal reports, and it is uncertain who within the team (physician, pharmacist, or nurse) should best carry it out. Although Poon's report only includes early pilot data, it seems apparent that health information technology will need to play a key role in making it easier and faster for providers to actually perform reconciliation. The application is currently being formally evaluated.

Although prescribing on personal digital assistants is being widely touted as superior to paper prescribing, few data have been available on their impact on the medication error rate, or how the error rate compares to the rate seen with prescribing on desktops. Thus, an evaluation published by Berner et al was of note [32]. They compared the safety of prescriptions for non-steroidal anti-inflammatory drugs (NSAIDs) between

two groups, one of which used personal digital assistants, with the control group using paper. They found that prescribing for these agents was about twice as safe using the handheld, which included a prediction rule for NSAID-related gastrointestinal risk assessment and treatment recommendations.

In another study, Simon et al evaluated the marginal effect of delivering age-specific alerts for potentially inappropriate medications in older people compared to non-age specific decision support, and also asked whether group academic detailing enhanced the impact of these alerts [33]. They found that making the alerts age-specific decreased the alert burden, while sustaining the effectiveness of the alerts.

In another geriatric study, in this case in the nursing home, for which there are very few data, Judge et al assessed prescribers' responses to alerts during medication ordering in long-term care [34]. They found that the number of alerts delivered was modest (about 2.5 per resident-month). However, prescribers who received the alerts were only 1.11 times as likely to take an appropriate action. Although this was statistically significant, the authors concluded that further refinements to such systems are required.

Another issue is that patient safety interventions may not be as relevant or as readily implemented in small or rural hospitals. To assess this question, Casey et al performed a study to determine how fully 26 safe practices identified by the National Quality Forum as the most important were actually being implemented in small hospitals in the U.S. [35] Hospitals overall had not implemented many of the safe practices. In addition, interventions relating to health information technology were ranked low in importance, suggesting that if these technologies are to be adopted either these hospitals will

need assistance or regulation may be necessary.

Finally, a challenging issue has been performing quality surveillance on an ongoing basis without relying on costly and labor intensive records review. Sims et al used multiple public health data sources to perform surveillance of methadone-related adverse drug events [36]. They found a 612% increase in emergency department visits over the period between 1997 and 2003, and their results also suggested that the increase in methadone prescribing over this interval was associated with a concurrent increase in methadone-related morbidity and mortality. A limitation that they had to deal with was that patient data were not linked between data sources. This work illustrates the opportunity to use routinely available data sets to identify potential adverse events.

Personal Health Records

The chronic disease management model first proposed by Wagner in 1998 is commonly being used as a framework for assessing interventions to improve functional and clinical outcomes in patients with chronic conditions [37]. (Figure 2) According to this model, a range of resources in the community and healthcare delivery system is required to have productive interactions between patients and providers in order to produce better outcomes. Traditionally, many healthcare information technology interventions have been directed at the encounter between a patient and physician in the office setting. However, reviews of interventions to improve glycemic control in patients with diabetes generally show that physician-targeted interventions may improve process but often achieve modest results with regard to patient outcomes. As a

result, there has been increased attention to the role of the activated patient—technologies that fall into this area include patient education, self-monitoring, and personal health records. In this section, we will take a closer look at personal health records (PHRs).

The Markle Foundation's Connecting for Health program defines the PHR as "an electronic application through which individuals can access, manage, and share their health information, and that of others for whom they are authorized, in a private, secure, and confidential manner." [38] The PHR may take a range of forms from a stand-alone application for a person to record their health information to an application that is fully connected with one or more electronic health records (EHRs). In an article in *Medical Economics*, Lowes describes the vision of the PHR as a single record "that follows the patient throughout his life and reflects the care he's received from any doctor or hospital, since their EHRs would hook up to the PHR." He delineates different types/functions of PHRs, including: [39]

- Enter/maintain information by the patient
- Import data from other sources, e.g. Pharmacy Benefit Manager
- Connect to EHR
- Communicate with doctors (securely)
- May be provided by payers/insurance companies
- Allow caregivers or family members to act as proxies

However, the current status of the PHR is described as "young" and "experimental" – the supporting evidence for benefits and business case is still evolving. In 2006, the Journal of the American Medical Informatics Association (JAMIA) published an article summarizing the American Medical Informatics Association College of Medical Informatics Symposium on the PHR, describing the potential benefits of the

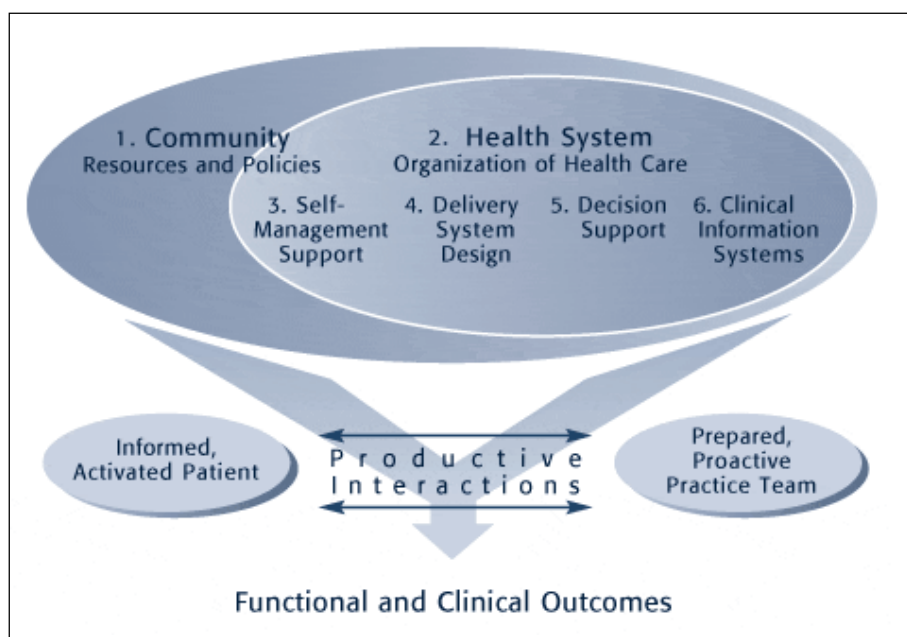


Fig.2 The Chronic Disease Management Model. From Wagner EH. Chronic disease management: What will it take to improve care for chronic illness? *Effective Clinical Practice* 1998;1:2-4.

PHR [40]. For the consumer, these potential benefits include access to credible information and data, and improved communication with healthcare providers. For clinicians, benefits include availability of patient-entered data, improved patient-physician relationship, and more efficient communication. For example, Geisinger Health System reports that they avoid 4000 phone calls per month because patients can electronically renew prescriptions, schedule appointments, and ask for medical advice [41]. In addition, PHRs are seen a potential differentiator to encourage consumers to choose among providers or to remain with their current providers [40]. Finally, benefits for payers may include decreased cost of managing chronic conditions and lower medication costs [38]. In order to establish a business case for PHRs, a key issue to be addressed is determining who will pay.

A paper by Grant and colleagues, published in *Diabetes Technology and*

Therapeutics, provides an example of the potential of PHRs [42]. They have designed a PHR intervention to address to key barriers to providing optimal diabetes care: (1) lack of patient engagement with therapeutic care plans and (2) lack of medication adjustment by physicians during encounters. They have developed a specific diabetes interface for their PHR (Patient Gateway) that imports the patient's current clinical data in an educational format, provides patient-tailored decision support, and helps the patient to author a Diabetes Care Plan. The effect of this intervention is not yet known and will be assessed as part of a randomized controlled trial. The intervention does illustrate the potential of using a PHR, coupled with an EHR and clinical decision support, to help activate the patient to produce better processes and outcomes of care.

Perhaps surprisingly much of the attention to and research on PHRs appears to be going on primarily in the United

States. We found little discussion of PHRs from other countries, despite the global importance of chronic diseases, and the fact that many nations are much farther along than the United States in EHR penetration, especially in primary care.

Clinical Data Exchange and Regional Health Information Organizations

The topics addressed thus far in this paper illustrate how information technology is being applied in the hope of improving quality and efficiency. In the case of PHRs, a key idea to move the boundaries of patient care from the doctor's office to the home. Another approach is to cross the boundaries between practices and institutions and achieve clinical data exchange. In 2005, Middleton and colleagues performed an assessment of the value of electronic health care information exchange and interoperability (HIEI) between providers (hospitals and medical group practices) and independent laboratories, radiology centers, pharmacies, payers, public health departments, and other providers, concluding that a compelling business case exists for national implementation of fully standardized HIEI [43]. Regional Health Information Organizations (RHIOs) are one approach to clinical data exchange, representing an interim step on the path to achieve the full-fledged vision of a National Health Information Network (NHIN). RHIOs are primarily a concept that is being tested in the United States, but the underlying principles of interoperability, data sharing, and record linkage are applicable to other countries, as well. In the United Kingdom, the approach has been to develop a single "spine," but this has been met

with considerable early resistance from the provider community [44].

Three early RHIO examples, initially developed under the Markle Foundation's Connecting for Health program were based in Indiana, California, and Massachusetts [45]. These RHIOs are now under contract to the United States Department of Health and Human Services. Lessons from these early organizations have been applied elsewhere—there are now at least 21 RHIOs in the United States.

In early 2006, the American Health Information Management Association (AHIMA) published an assessment of the current state and key issues about RHIOs [46]. The assessment is a summary of the eHIM Working Group's findings on the current status and record linkage methods for 21 RHIOs in the United States. Following are some of the main points of their findings. The purpose of RHIOs is seen as improving healthcare delivery by providing secure, confidential exchange of health information between authorized users, reducing medical errors and adverse drug reactions, and encouraging the participation of patients in their own healthcare. Funding sources of RHIOs vary, including grants, incentives, and private funding—the business models are still evolving. In *HealthCare Informatics in 2006*, Raths notes that a key challenge for RHIOs is how to support information exchange and quality improvements given the constraints of the current reimbursement model [47].

Since AHIMA represents health information management professionals, they take a particular interest in record linking methods, describing the range of methods that can be used to match individuals in different systems or data sets. The challenge is to avoid false positives, i.e. do not incorrectly conclude that two individuals represent the same person, while minimizing false

negative, i.e. not matching two individuals who actually do represent the same person. While duplicate records (false negatives) are a problem, record linking methods must generally err on the side of avoiding false positives. Methods for linking records range from basic matching, comparing specific data elements like name, social security number, and date of birth, to advanced, using sophisticated mathematical techniques like probabilistic matching, bipartite matching, machine learning, and neural networks.

Data access methods in RHIOs range from real-time access via computer applications to use of the telephone or facsimile. Among the 21 RHIOs examined by AHIMA, accessible data included demographics, payer, orders, medications, radiology images, notes, allergies, laboratory results, immunizations, and eligibility information. In almost all cases, there was no centralized data repository—data remained distributed and under the control of the originating institution with access on-demand through predefined protocols and methods. Connecting for Health has released a “Common Framework” of technical and policy structures that have been demonstrated to work with regard to accessing and exchanging data [48]. Overall, achieving clinical data exchange appears to hold great potential benefits, but also presents substantial difficulties, both technical and societal. The best architectures for this, for example, are still being determined. Addressing these difficulties will likely represent one of the next key challenges in medical informatics.

Conclusions

In this paper, we have addressed 5 areas that we believe will be central to informatics research in the years to

come: changing provider behavior and improving outcomes; secondary uses of clinical data; using HIT to improve patient safety; personal health records; and clinical data exchange. A great deal of research has been done on changing provider behavior, but it remains unclear about the extent to which the lessons learned will be domain-specific, and most work to date has shown that process benefits are much easier to achieve than outcomes benefits, especially for chronic diseases. Using secondary data better clearly has enormous potential. It is now clear in most nations that patient safety represents a major problem, and one of the key tools for improving it will be HIT—many more studies of different approaches are needed in this area. Finally, both personal health records and clinical data exchange appear to be potentially transformative developments, but much of the published research to date on these topics appears to be taking place in the U.S., and much more research from other nations is needed.

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