Available online at www.sciencedirect.com

ScienceDirect

Journal of Biomedical Informatics 40 (2007) 398–409

Journal of Biomedical Informatics

www.elsevier.com/locate/yjbin

Redesigning electronic health record systems to support public health

Rita Kukafka [a,b,*], Jessica S. Ancker [a], Connie Chan [a], John Chelico [a], Sharib Khan [a], Selasie Mortoti [a], Karthik Natarajan [a], Kempton Presley [c], Kayann Stephens [a]

[a] *Department of Biomedical Informatics, Columbia University College of Physicians and Surgeons, 622 W. 168th Street, Vanderbilt Clinic VC5, New York, NY 10032, USA*

[b] *Department of Sociomedical Sciences, Mailman School of Public Health, Columbia University, NY, USA*

[c] *Department of Health Policy and Management, Mailman School of Public Health, Columbia University, NY, USA*

Received 5 April 2007
Available online 9 July 2007

Abstract

Current electronic health record systems are primarily clinical in focus, designed to provide patient-level data and provider-level decision support. Adapting EHR systems to serve public health needs provides the possibility of enormous advances for public health practice and policy. In this review, we evaluate EHR functionality and map it to the three core functions of public health: assessment, policy development, and assurance. In doing so, we identify and discuss important design, implementation, and methodological issues with current systems. For example, in order to support public health's traditional focus on preventive health and socio-behavioral factors, EHR data models would need to be expanded to incorporate environmental, psychosocial, and other non-medical data elements, and workflow would have to be examined to determine the optimal way of collecting these data. We also argue that redesigning EHR systems to support public health offers benefits not only to the public health system but also to consumers, health-care institutions, and individual providers.

Keywords: Public health; Decision support; Surveillance; Assessment; Assurance; Policy development; Patient-centered health records

1. Introduction

American hospitals and physicians' offices are gradually adopting electronic health record (EHR) systems, with the goals of improving patient care and outcomes; increasing efficiency and lowering costs; improving billing procedures; reducing the frequency of lost records, data, and medication errors; and providing better access to patient histories [1,2]. Electronic health record systems can incorporate clinically useful features such as electronic alerts, guideline reminders, and automatic monitoring of quality of care indicators [3]. EHR systems are most often cited for their potential to reduce medical errors through decision support such as adverse drug interactions [4], and they also have the potential to provide other benefits such as reducing drug costs [5] and making medical history data available during emergency care [6]. President George W. Bush has advocated universal adoption of electronic health records by 2014, with the help of the Office of the National Coordinator for Health Information Technology under the Department of Health and Human Services [7].

Despite these advantages, a variety of barriers have slowed the adoption of EHRs in American healthcare settings. Only 5–10% of US hospitals use EHR systems [8], and overall, less than 18% of US providers use them [9]. The rate is even lower among small ambulatory care providers. Ford et al. estimated that by 2014, adoption among small practices will be between about 56% and 72% [9]. Thus, the need for electronic health records systems has been recognized, but the systems themselves have not been widely implemented.

---

[*] Corresponding author. Address: Department of Biomedical Informatics, Columbia University College of Physicians and Surgeons, 622 W. 168th Street, Vanderbilt Clinic VC5, New York, NY 10032, USA. Fax: +1 212 305 3302.

E-mail address: rita.kukafka@dbmi.columbia.edu (R. Kukafka).

1532-0464/$ - see front matter © 2007 Published by Elsevier Inc.
doi:10.1016/j.jbi.2007.07.001

The present moment, between the recognition of the need for healthcare IT and the fulfillment of that need, provides important opportunity to examine the purposes and design of EHR systems. Important functionality should be built into systems at the beginning because retrofitting them later could be prohibitively expensive [10]. In this review, we argue that the current conception of an EHR system is strongly clinical in focus, but that these systems could serve important public health goals through two broad categories of changes. The first category would ensure that clinical data could be reused for public health purposes; much of this reuse would be invisible to current clinical users except where it reduced paperwork burdens and improved clinical decision support. The second category of changes advocated in this paper would expand the clinical data model to collect and process new types of data including psychosocial, behavioral, and environmental variables; this expansion would have to be handled carefully to add value without adding new data collection burdens on clinicians. (A third issue that is critically important but beyond the scope of this article is strong privacy and security protections that will allow data-sharing and patient-record matching without compromising the privacy of personal health information. The adequacy of such provisions in current health information infrastructure plans has been challenged [11,12], and the issue will have to be resolved in order to promote trust in any health information exchange.)

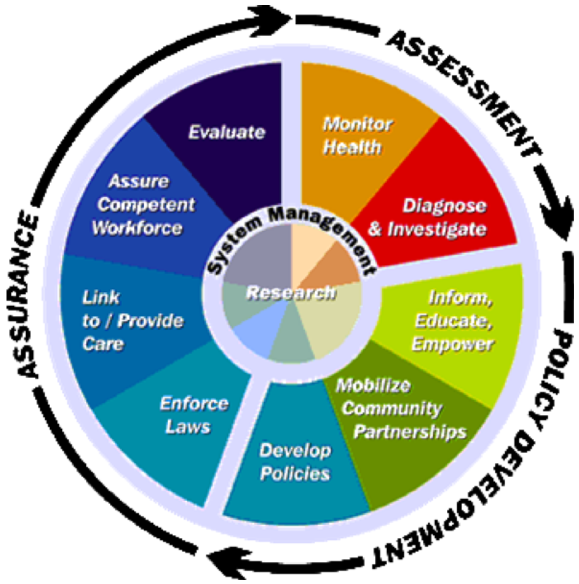

Fig. 1. The core functions and essential services of public health. Reprinted from Public Health Functions Project of the US Department of Health and Human Services (1995, http://www.health.gov/phfunctions/public.htm); permission pending.

In this review, we discuss the goals of public health, the methodological implications of adapting clinical EHR systems to serve these public health goals, and likely incentives

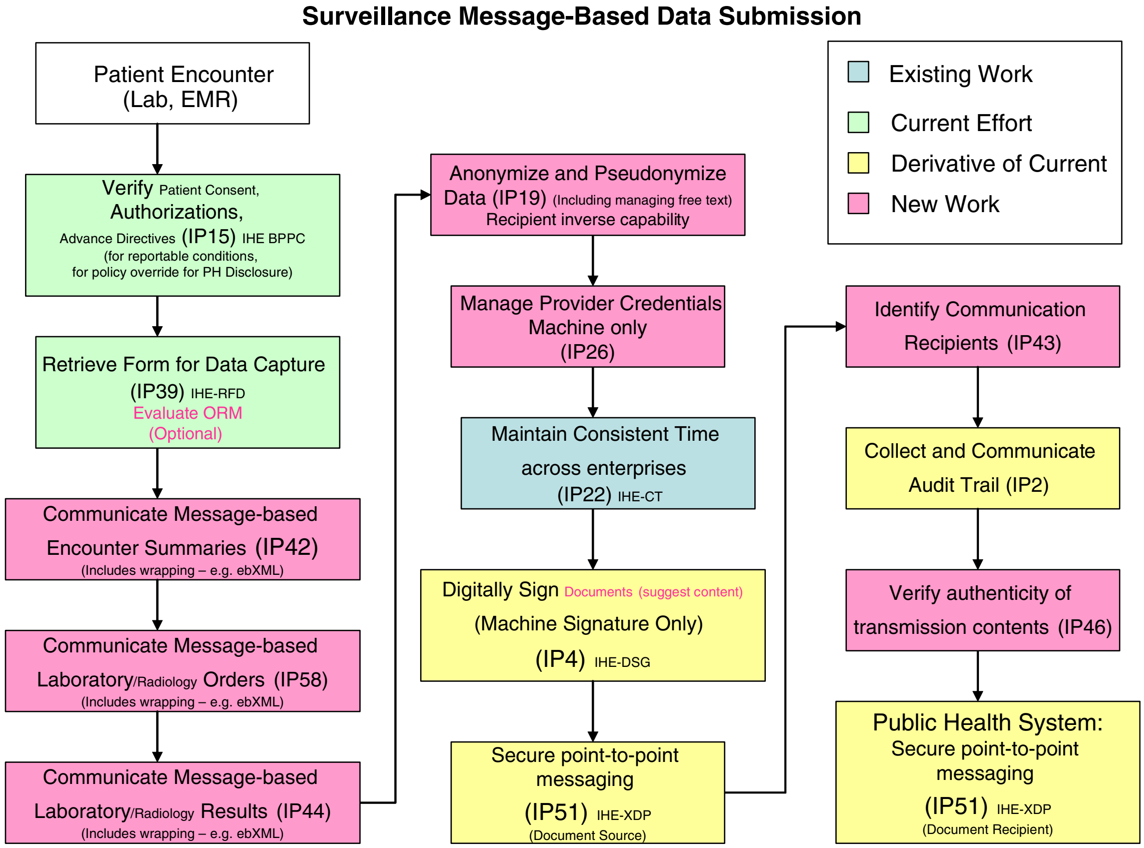

Fig. 2. Proposed data submission workflow in biosurveillance use case. Adapted from [30] permission pending.

and challenges these adaptations would pose to a variety of stakeholders. We further present a framework to connect public health goals to established informatics methods to draw attention to those informatics methods that can be applied directly or extended and modified to help EHR systems to address public health goals and challenges.

1.1. The goals of public health and the clinical orientation of current EHRs

A widely accepted definition of public health outlines three core functions: assessment (i.e., assessing the state of public health), policy development (i.e., developing policies to promote health), and assurance (i.e., assuring that these policies are implemented) [13,14] (Fig. 1). Public health practitioners generally place disease and disability in context of societal, behavioral, and environmental factors, and the public health system thus seeks measures that can benefit populations though social and legal policy, and behavioral and environmental intervention. A public health perspective also tends to emphasize applying population data to individuals; clinicians draw from this perspective when they generalize from epidemiological studies and clinical trials to individual clinical care. Public health typically emphasizes preventing disease rather than simply treating it after it has occurred. The local, state, and federal public health agencies in the US perform a staggering variety of functions: collecting and analyzing vital statistics and other population-level measures of health status; tracking specific reportable diseases and investigating epidemics; promoting healthy behavior to patients and health consumers and through social marketing and public policy; ensuring safe food and clean drinking water; maintaining disease and vaccination registries; providing direct clinical care, especially preventive care, through community clinics; supporting research; and providing a wide variety of other services. Ten essential services of public health have been enumerated [13] (Fig. 1):

- *Core function: assessment*
  Service: Monitor health status to identify community health problems.
  Service: Diagnose and investigate health problems and health hazards in the community.
- *Core function: policy development*
  Inform, educate, and empower people about health issues.
  Mobilize community partnerships to identify and solve health problems.
  Develop policies and plans that support individual and community health efforts.
- *Core function: assurance*
  Enforce laws and regulations that protect health and ensure safety.
  Link people to needed personal health services and assure the provision of health care when otherwise unavailable.
  Assure a competent public health and personal health care workforce.
  Evaluate effectiveness, accessibility, and quality of personal and population-based health services.
- *Serving all functions*
  Research for new insights and innovative solutions to health problems.

Currently, electronic health record systems focus on the individual patient care provided by clinicians and hospitals [10]. The clinical orientation of these systems is clear in two widely accepted descriptions of ideal EHR systems. The first, developed by Health Level Seven (HL7) and backed by the American National Standards Institute, is a functional model that outlines a gold standard that EHR systems should strive to meet [15,16]. This list describes and defines EHR functionalities to ensure clear communication about EHR systems, and sets a benchmark for evaluating systems. As Mon points out, no current product meets all the HL7 requirements [15]. The second requirements list was created by the Certification Commission for Health Information Technology (CCHIT), a Chicago-based nonprofit organization that was given the task of selecting a certification criterion by the United States Department of Health and Human Services [15]. Excerpts from current CCHIT criteria are in Table 1 [17]; lists of currently certified EHR systems for ambulatory care are available at www.cchit.org. Both HL7 standards and CCHIT criteria focus on managing and exchanging health-care information reliably and securely on a patient-by-patient basis. For example, CCHIT's interoperability standards (Table 1) focus on ways to improve individual patient care by ensuring that lab and medication data can be exchanged electronically in a seamless fashion; there is no mention of providing automated public health data reporting or using data to support medical research. Clinician-oriented functions include clinical decision support at the point of care, but there is no discussion of ways for patients to participate in maintaining their health record or obtaining information from it.

In discussing the methodological implications of adapting clinical EHR systems to serve these public health goals, we focus this paper on the three core functions of public health: assessment, policy development, and assurance.

2. Assessment

Assessment is aimed at collecting relevant and up-to-date public health information, especially information about health status, community health needs, and health problems, for provision to the public, healthcare providers, and policymakers [13]. Although infectious disease surveillance and assessment are traditionally core functions of public health, they began to be downplayed in the second half of the 20th century during the golden age of antibiotics. For example, in 1962, that year's Nobel laureate in medicine, the Australian physician Sir F. MacFarlane

Table 1
CCHIT certification criteria for the electronic medical record system

Functionality	Identify and maintain the patient record Manage patient demographics Manage problem list Manage medication list Manage allergy and adverse reaction list Manage patient history Summarize health record Manage clinical documents and notes Capture external clinical documents Generate and record patient-specific instructions Order medications Order diagnostic tests Manage order sets Manage results Manage consents and authorizations Manage patient advance directives Support for standard care plans, guidelines and protocols Capture variances from standard care plans, guidelines and protocols Support for drug interaction Support for medication or immunization administration or supply Support for non-medication ordering (referrals, care management)
Security	Access control Audit Authentication Technical services
Reliability	Backup/recovery Documentation Technical services Present alerts for disease management, preventive services, and wellness Notifications and reminders for disease management, preventive services, and wellness Clinical task assignments and routing Inter-provider communication Pharmacy communication Provider demographics Scheduling Report generation Health record output Encounter management Rules-driven financial and administrative coding assistance Eligibility verification and determination of coverage Manage practitioner/patient relationships Clinical decision support system guidelines updates Entity authorization Enforcement of confidentiality Data retention, availability and destruction Audit trail Extraction of health record information Concurrent use
Interoperability	Laboratory and imaging Medications Immunizations Clinical documentation Secondary uses of clinical data Administrative and financial data

Adapted from: www.cchit.org.

Burnet, declared in his text *The Natural History of Infectious Disease*, “to write about infectious disease is almost to write of something that has passed into history.” Seven years later, the US Surgeon General, William Stewart, testified to Congress that “it was time to close the book on infectious diseases.” [18] However, this function has become particularly relevant to biodefense and has become of central importance to public health and the most active area for public health informatics research.

Currently, the public health establishment assesses population health status and problems through such measures as surveys, vital statistics reporting, and paper-based systems for reportable disease notification. None of these methods provide anything close to real-time data collection, such as would be needed for biosurveillance. Furthermore, for reportable diseases, clinicians and institutions have a low compliance rate [19], raising concerns about the accuracy of estimates made from the resulting data. Thus, public health assessment cannot become efficient or effective without "accurate, valid, and cost-effective" collection of electronic data from the point of care, as well as dissemination of results back to the point of care [10]. The importance of the EHR system in public health assessment has been outlined succinctly by Chute and Koo: (1) a large proportion of the data relevant to public health derive from clinical data, and (2) these data should be collected once and then reused, rather than collected repeatedly by different users [20]. Repeated collection of the same data by different individuals introduces needless data collection burdens, as well as data entry error. A completely interconnected health information infrastructure, the topic of the Markle Foundation's report "Connecting for Health," could ensure rapid, complete, and secure reporting [19]. Such an infrastructure would support disease reporting from EHR systems to public health agencies, which could be automated to eliminate the current paperwork that burdens providers.

Sharing clinical data would not obviate the need for carefully designed surveys and other types of public health studies. It is possible that much of the data collected for clinical purposes may be too noisy and poorly controlled to be useful for aggregation across populations. Nevertheless, data mining from aggregated clinical data is an active area of research producing promising results [21]. Additional applications could result from integrating clinical data with data from other sources in real time [22] such as pharmacies, registries, emergency responders, and vital statistics bureaus [23]. Such integration could provide a boost to both traditional epidemiological surveillance, which involves monitoring disease outbreaks, and syndromic surveillance, in which precursors such as over-the-counter medication purchase patterns and absenteeism data are monitored to detect subclinical syndromes or provide early warning of future health problems [24]. For both types of surveillance, public health data systems will have to be able to integrate data from a variety of different sources and pool them for epidemiological analysis or data mining. Currently in the US, public health data collection tends to result in isolated caches at the local, state, or federal levels [20].

2.1. Data standards for sharing data

The absence of consensus on data standards in terminology, messaging, data structures, and data recording remains a primary barrier to an interoperable infrastructure, although progress has been made on this topic [20,25]. Even within institutions that have adopted HL7 Version 2 messaging protocols, the standard allows users to create fields for institution-specific purposes; the resulting differences in the message format can make it difficult to transmit messages across institutions. Thus, tighter standards will need to be implemented for complete interoperability. Furthermore, current vocabularies such as MeSH typically do not have thorough coverage of public health concepts and terms [26]. The ICD-9-CM (International Classification of Diseases, Ninth Edition, Clinical Modification) is one of the more widely used terminologies because it is used for billing, but captures relatively few of the clinical details that would be useful for surveillance [20]. New concept-based public health vocabularies may need to be expanded or a controlled public health vocabulary developed; the Public Health Conceptual Data Model published by the CDC as part of the National Electronic Disease Surveillance System (NEDSS) projects is an attempt to bring together this work and put it on a conceptual basis [27]. Another hurdle is that some existing standards have not been widely adopted in practice; an example is the standard for microbiology reports [19]. Ultimately, public health organizations, medical groups, and other stakeholders need to publicize and agree upon these standards [28]. Both HL7 and the Markle Foundation's Data Standards Work Group have done extensive work in analyzing the current standards and developing additional standards that would be essential for an interconnected system [19].

Ensuring interoperability of EHR systems is obviously not the only issue. The anthrax terrorist attacks of 2001 (in which powdered spores were mailed to several public figures and news organizations) revealed deficiencies in the ability of public health agencies to process data received from multiple sources in real time [23]. Thus, improvements in the capabilities of the public health information systems are also needed.

Biosurveillance requires near-real-time event monitoring to enable early event detection and rapid response [29]. HITSP's Biosurveillance Technical Committee has done extensive work on standards and interoperability issues for biosurveillance, employing a use case that involves transmitting ambulatory care, emergency department visit, utilization, and lab results data in standardized and anonymized format to public health agencies within one day. Steps in biosurveillance data transfer (Fig. 2) will include identifying relevant information, aggregating data, and anonymizing it, formatting it to public health specifications, identifying the relevant public health agencies, transmitting the data to them, and logging all transactions. Data could be sent data directly from individual health-care organizations, through some intermediary networked organization, or through a combination of models. Importantly, this standards project is being harmonized with that of the EHR. The Biosurveillance Technical Committee has published extensive reports [30,31] on standards needed to support this goal, as well as on remaining interoperability issues. For example, no consensus has emerged on the components or ontology of the 'essential data set' for biosurveillance, although this may be interactive and situation-dependent [30,31].

2.2. Expanding the clinical data model

Such data standards would ensure that currently collected data could be shared, but they would not be sufficient to ensure that the correct data were collected in the first place. To address this issue, the Healthcare Collaborative Network (HCN), a consortium of private and public health institutions, was created to follow up on the "Connecting for Health" project. One of its goals is to support reporting by identifying the essential data needs of various federal agencies; identifying which kinds of data are needed at the population-level could help ensure that they are collected at the point of care [19]. Implementing this type of expansion requires rethinking and expanding the health data model.

Public health has always recognized that health is dependent upon multiple factors, including individual characteristics, the community, the environment, and a host of social and psychological factors. Yet current EHR systems seldom capture data elements other than clinical ones. Fig. 3 illustrates one potentially useful way of categorizing the multiple levels of health and disease influences [32]. Each of these levels contains a large number of data elements that have been used to study specific health outcomes or pathogenic sociobehavioral or biological process. Some of these elements are shown in Table 2: the environmental level includes such elements as stressful life events, social support and environmental hazards; the behavior/psychological level includes dietary practices, stress coping styles, and tobacco use; the organ systems level includes the cardiovascular, endocrine, immune, and central nervous systems and their outputs; the molecular or genetic level includes such elements as DNA structure, proteins, mRNA, and transcription factors. Public health interventions may focus on more than one level, using a variety of strategies to mitigate the factors known to contribute to the disease process. For example, in coronary health disease, social-level risk factors include socioeconomic status and social support; behavioral-level risk factors include physical inactivity and smoking; and organ systems-level risk factors include low-density lipoproteins and hypertension.

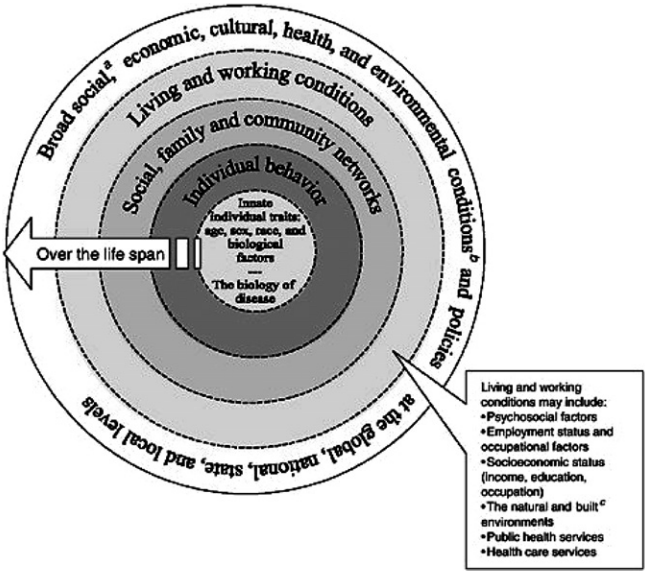

Fig. 3. Population health is determined by factors at multiple levels. (a) Social conditions include, but are not limited to: economic inequality, urbanization, mobility, cultural values, attitudes, and policies related to discrimination and intolerance on the basis of race, gender, and other differences. (b) Other conditions at the national level might include major sociopolitical shifts, such as recession, war, and governmental collapse. (c) The built environment includes transportation, water and sanitation, housing, and other dimensions of urban planning. Reprinted from [14]; permission pending.

It is not possible to extend the EHR data model to capture the entire host of factors, but an EHR's data model should represent those data elements that are known to contribute to the disease process in order to provide decision support and/or data transfer to public health authorities when there is a known clinical or public health intervention. Guidance on what data elements to include may be gleaned from the Chronic Care Model [33] developed to reformulate healthcare from an acute care model in managing chronic diseases into a public health model. The model combines prevention efforts that incorporate community resources, self-management, and multidisciplinary practice teams into the health-care system that includes decision support, delivery system design, and clinical information systems. Jilcott et al. incorporated this model into a decision support system when they assessed community-level and environmental factors that may be impediments to healthy lifestyles, measured patient perceptions of these neighborhood barriers, and then linked community resources to the recommendations that were offered by providers at the point of care in a clinic-based intervention to prevent cardiovascular disease [32]. Therapeutic lifestyle counseling, recommended by clinical preventive guidelines, can also be supported by an EHR when the data model is broadened to include psychosocial data element. For example, the Screening for Metabolic Syndrome in Adults Guidelines [34] recommend assessing psychosocial and economic issues during a first-encounter assessment: factors include living situation, cooking facilities, finances, educational background, literacy, employment, ethnic or religious belief considerations, family support, and food assistance. An EHR that does not include the elements needed to conduct this assessment will fall short in offering the provider evidence-based guidance.

2.3. Improved surveillance using the EHR extended data model

Extending the data model offers the promise of valuable returns to the health-care provider for chronic

Table 2
Connections between public health goals and informatics methods

Public health core function	Examples of component activity	Extension or modification of informatics methods	Examples of return to stakeholders
Assessment	Syndromic and traditional surveillance	*Knowledge elicitation:* work with public health experts to expand the clinical data model to include a multifactorial view of health and disease	Identify impending epidemics or attacks early in the continuum of the disease process
		Knowledge representation, terminologies: representing and integrating heterogeneous data from multiple sources; adding new concepts and terms to EHR vocabularies	Improve accuracy and timeliness of data on disease prevalence
		Standards: developing and applying standards for interoperability between public health, clinical data sets, and community-based organizations	Ease data collection/reporting burden on individual health-care providers and institutions
		Database methods, communications: integrating data distributed across databases (e.g., environmental, retail, employee) for epidemiological analysis or data mining; automating disease reporting	Improve communication among public health agencies to improve preparedness and speed response
		Machine learning, data mining, epidemiologic methods: asking and answering population-level questions through public data sets	Provide community-level data to clinicians at point of care
		Mapping, GIS: integrating health data with geographical data; Analyzing and visualizing geographic data	
Policy development	Developing public policy	*Decision analysis:* making optimal public-level decisions from assessment data	Ease cognitive burden of using public health guidelines through well-designed decision support
	Informing and empowering people about health issues	*Cognitive science, group dynamics, naturalistic decision science, HCI, visualization:* disseminating information to providers and consumers; persuading and improving decisions	Empower consumers to learn about health issues
		Decision support: integrating public health guidelines into clinical-level decision support; Developing population-level decision support for agencies and governments and consumer decision-support for the public	Ease public policy development and communication with appropriate tools
Assurance	Evaluating quality of health services	*Database methods, communications:* automated quality indicators at the institutional level; automated reporting to agencies	Ease data collection/reporting burden on institutions
		Cognitive science, naturalistic decision science: communicating quality data to the public and policy makers	Improve accuracy and timeliness of quality data
			Better use of quality-of-care data

disease prevention and management, as described above, as well as improving decision support using surveillance data by providing critical information both to the clinician and the public health system [10]. The current HL7 standard for EHR systems recommends collecting data about antibiotic resistance; interoperability between systems could result in valuable community-level information about local antibiotic resistance trends (antibiograms), which could be provided back to the clinician at the time of order entry as part of a decision support system. This would help ensure that the clinician reaps the benefit of the data he or she helped to collect, and provide real-time assistance at the point of care. An example of a functioning public health surveillance system is the Real-time Outbreak and Disease Surveillance (RODS) system, currently in use in Pennsylvania and Utah. Hospitals send RODS data in real time as they are collected at physician–patient encounters in emergency departments and pharmacy transactions; these data are transmitted over wide area networks using the HL7 messaging standard [22,35,36].

By recognizing the multiple causal levels of morbidity, mortality, and disability endpoints consistent with the expanded health data model, surveillance research could not only track changes in disease rates and emerging outbreaks but also explain the reasons for observed disparities and trends in this disease burden. Historically, population-based surveillance has served more of a descriptive and hypothesis-generating function. Surveillance research using EHRs with a public health extended data model could be used to enhance the public health surveillance function so that it could also clarify the connections between changes in risk factors and early detection behaviors and disease outcomes, as well as the influences of the quality of health services and clinical treatment on disease survival, quality of life, and mortality. This type of an enhanced surveillance system is a major National Cancer Institute goal incorporated into their strategy for cancer research in the 21st century [37].

2.4. Benefits to providers

Links with community health data can benefit providers at the point of care. An example of a bidirectional communication link between public health surveillance and clinical practice is demonstrated by Fine et al. [38]. Factoring in community-level disease trends when estimating disease likelihood was shown to improve the performance of an existing clinical decision rule in distinguishing aseptic from bacterial meningitis. Epidemiological context improved the performance of a clinical prediction rule, providing a framework for leveraging surveillance data to improve clinical decision-making at the point of care.

2.5. Some methodological challenges

Using clinical data for surveillance would be facilitated by reliable automated methods for identifying cases from clinical records. Yasnoff and Rippen point out that current population estimate of the prevalence of conditions such as diabetes are made by extrapolating from the National Health Interview Survey (NHIS), which asked participants whether they had ever been told by a health professional that they had diabetes [10]. Using clinical records could potentially be more accurate than relying upon personal recollections. Laboratory data such as hemoglobin A1C and diagnostic codes used for billing are potential sources of clinical information. However, administrative coding has frequently found to be flawed [39] and is unlikely to be reliable as a sole source of information. An additional source could be free-text records such as clinical summaries and radiological reports. This would be needed for example, to apply CDC criteria for the clinical case definition of tuberculosis, which includes findings from radiological chest X-ray reports as well as from medical signs. Unfortunately, in view of the richness of natural language and the many ways clinicians describe findings; it is difficult for current automated systems to process free text with the accuracy that would be needed. Accuracy of current systems varies widely and generally depends upon context. In one study on automated tuberculosis detection on free-text radiology reports, the natural language processor had a 92% agreement with a clinician's opinion [40]. However, in another study on automatic detection of radiologically positive anthrax, a probabilistic model for detecting chest radiograph reports describing anthrax findings had a sensitivity of 85.6% and positive predictive value of 41% [41]. Improvements in current medical natural language processing (NLP) techniques would therefore serve to bolster the drive for automated public health surveillance.

Integrating individual-level data is challenging in the absence of a unique personal identifier. Nevertheless, a "person-based" data repository is a necessity to ensure that data can be matched horizontally across sources and longitudinally over time [28]. Some groups have therefore advocated a unique personal identifier system, but others are concerned about the privacy risks and Congress has currently restricted the Department of Health and Human Services from pursuing this option [28]. Reaching agreement on this controversial topic is a difficult public policy issue.

3. Policy development

Data from such an integrated electronic health system would be invaluable in informing policy makers at the local, regional, and national levels to help ensure that policies are grounded on a solid scientific basis. In addition, informing and empowering the public are important goals of policy development in public health [13].

It may be useful to clarify that although assessment of health status and its determinants is an assessment function, the task of informing, educating, and empowering people about health issues and the task of mobilizing community partnerships to identify and solve health problems fall under the policy development core function of public health. For example, an event monitoring system that triggers an alarm in the event of an aberration originates in the assessment function, but the extent to which the system facilitates appropriate and data-driven public health response to that alarm is policy-related. That is, the choice of appropriate triggers for action and the choice of action are both policy-related. We have accordingly followed the IOM categorization [13] by discussing surveillance and event monitoring as an assessment function, and informing and involving the public, community groups, and partners as a policy function.

3.1. Informing and involving community groups and policymakers

Decision support systems, including reminders and alerts, could be expanded to include not only clinicians but also community groups and policy makers. For example, an event monitoring system could make trend information available to the local health department or send an alert if it exceeded some predetermined threshold. The event monitoring system would have to be able to determine when to report on an individual and when to report on a group or population [25]. CDC public health guidelines were evaluated to determine if they could be disseminated through EHR systems [42]. These authors found that 360 of the 1069 guidelines contained at least one recommendation that could be used as an alert to the physician during a patient visit [42]. Childhood immunization guidelines from the CDC are a prime target for electronic alerts because the schedules can become quite complex [10]. Adding more alerts to a decision support system could cause dissatisfaction and overload, so multidisciplinary cognitive, behavioral, and organizational research would be needed to prioritize such potential alerts across fields and topics.

In Canada, the Canadian Community Monitoring Network (CCMN) project is using community-based monitoring information to better inform policy and decision-makers, and to build local capacity to collect, deliver, and use ecological information to facilitate sustainable decision-making [43]. While initially focusing on specific aspects of the environment (water, wildlife, deposition of contaminants, etc.), the model can be extended to include the EHR to send relevant data to decision makers in the community to combine with environmental monitoring data. Another example is VistaPHw, a Web-based data query system that provides access to population-based data used in community health assessment [44]. VistaPHw facilitates the production of results that are relevant to public health decision-making. The software is used to monitor trends, track health disparities, and detect emerging community health problems. VistaPHw provides access to a wide range of datasets commonly used in community health assessment. Dynamic grouping has helped mobilize resources for community interventions, build community partnerships, and provide data for program planning. Currently, the system uses population-based datasets and has utilities to include small area population estimates and geocoding event data. Similar Web-based data query systems are currently used in 27 states. Datasets included vary from state to state but typically include those related to vital statistics (such as births and deaths), population, behavioral risk factors, and cancer incidence [45]. An extension could incorporate point-of-care data generated by the EHR for a more integrated and timely view of the community, providing that the system includes cases from the community seen in a large enough range and representative sample of health clinic sites, and that it omits cases from outside the community.

3.2. Informing and involving the public

EHR systems could offer new opportunities for patient involvement in their own medical care, including informing patients through new methods and promoting a sense of ownership of their health information. A patient-oriented EHR could represent a major departure from the classic patient health record, which has traditionally remained in the hands of the clinician.

EHR systems could be used to expand patient education opportunities. Among the benefits of good patient education are "improved self-reported health status, lower health-care costs, increased health knowledge, shorter hospitalizations, and less frequent use of health-care services" [46]. Electronic systems could help produce tailored preventive health information, reminders, and alerts based on personal clinical records that could be sent directly to individuals [47]. The NLP research cited earlier could assist in identifying potential tailoring variables; in addition, continuing behavioral research is needed to identify optimal tailoring characteristics and desirable communication formats (options include electronic communication, telephone, hard copy materials, and DVDs or other multimedia options). As with providers, notifications or alerts to patients must be accurate and cannot be too numerous or onerous [48].

Effective communication between patients and providers can lead to improved clinical outcomes and contributes to patient education [49]. The EHR system could facilitate patient–provider communication by providing suggestions or scripts for providers on how to discuss sensitive topics, providing background information for patients to read after the visit, and facilitating email or telephone follow-up, initiated either by the patient or the provider. More access to physicians through telephone, email, or Internet message board consultation is one of the needs repeatedly mentioned by focus groups in underserved areas of Harlem (unpublished focus group data, Kukafka et al.).

To support such functions such as point of care patient education, we revisit the need for the public health extended data model and the discussion on therapeutic lifestyle counseling (TLC) in preventive guidelines. It is well understood that TLC requires medical, psychosocial, and intervention grounded in behavioral science [50,51]. However, few EHR systems collect patient information on these broad arrays of elements. An EHR that captures such multilevel data (Fig. 3) can be a tool to support evidence-based provider counseling and patient recommendations that comply with the therapeutic lifestyle counseling recommendations in clinical preventive guidelines. This can improve current practice where TLC recommendations are too often "medicalized" [52]. For example, consider the new diagnosis of metabolic syndrome, which includes (at least) glucose intolerance, obesity, hypertension, and dyslipidemia [53]. The physiological components can be treated with medicines, with the underlying behaviors (overeating and lack of exercise) treated with counseling. However, since current EHR systems do not support the TLC recommendations of CPGs and the providers at most community health centers and other physician practices have inadequate resources, it is often simpler to provide the medicines and let the counseling slide. This practice is made worse because providers receive little training in behavioral counseling and, with the average patient encounter lasting 15 min or less, many providers have little time to conduct psychosocial assessments or provide focused behavioral counseling and support according to the TLC recommendations. Decision logic for generating tailored provider counseling and patient self-management recommendations through an EHR cannot be evidence-based if it does not include the medical, psychosocial and behavioral social-cognitive aspects of TLC and risk management.

There has been relatively little discussion of using the EHR system to allow patients to access, contribute to, or correct their own medical records. Patient report is likely to improve record quality, according to a study in which patients were invited to correct their medical record [54].

These patients provided important information that had been missing in the record, which improved the completeness of the medical record including their documented adherence to health maintenance procedures [54]. Direct patient input might also be useful in collecting social, behavioral, and demographic information that is not typically collected at a visit with a clinician, but that might be useful in tailoring interventions from a public health perspective. For example, patients could contribute information about personal stress levels or home and family environment, or they could complete depression screening or other instruments. Implementing this type of expansion requires rethinking and expanding the health data model. Patients in fact, may be best suited to provide information for several of the data elements shown in Fig. 3. Increasing patient involvement with the medical record would be likely to contribute to health literacy and create a sense of ownership of their health information. Potential beneficial outcomes include becoming more involved in the health-care process, making better treatment decisions, and learning how to cope with disease and pursue healthy behaviors [25].

3.3. Some methodological challenges

Facilitating patient involvement at this level requires a radical rethinking of how to present the information in the record. First, highly usable interfaces will have to be developed to accommodate a variety of levels of computer literacy. Second, the medical data will have to be interpreted and explained to the patient. In the PatCIS project, a select group of patients with chronic illness were given view-only electronic access to their EHR through the Web [55,56]. Patients who used it were most likely to use it to view their laboratory results after a visit. However, overall use of the system was relatively low; it is possible that providing interpretation and translation of the raw medical and laboratory data would make it much more useful to lay individuals [57].

4. Assurance

Assurance functions involve efforts to set goals and priorities that ensure the public of quality and timely public health services [13].

4.1. Providing health care to those in need

One of the essential assurance services of public health is to “[l]ink people to needed personal health services and assure the provision of health care when otherwise unavailable” [13]. Current EHR systems reside in hospitals or clinician offices and thus operate under the implicit assumption that individuals have regular providers. However, 46 million Americans—nearly 16% of the population—have no health insurance [58]; these individuals typically have no regular health-care providers and tend to use emergency rooms for primary care and non-urgent services [59]. Under current market-driven conditions, these patients would likely be the last to obtain electronic records, even though they would be highly likely to benefit from them because they are more likely to seek care in emergency rooms, and when they seek primary care at all, to switch providers frequently depending upon affordability. Another group of individuals who seem unlikely to obtain EHRs under current conditions are those served by small independent practices serving high proportions of Medicaid, Medicare, and fee-for-service patients; most Medicare fee-for-service visits, for example, are to providers with little or no patient-oriented information technology [60]. For this reason, a pilot program by the New York City Department of Health is developing a low-cost EHR system to be provided at reduced cost to such small medical practices to help reach uninsured patients and those served by less wealthy providers (unpublished data, Farzad Mostashari, NYC DOH). Using $27 million in mayoral funding, the Department of Health will extend EHRs to more than 1000 primary care providers who serve disadvantaged populations. Another reason to promote interoperability is to promote continuity of care for the 13% of people with usual sources of care who change their medical provider each year, according to the Community Tracking Survey [61].

Creating EHR systems for uninsured patients raises important policy questions about where the data will reside. The holder of the data must be able to ensure security, confidentiality, privacy, access, and reliability, but also must hold the public’s trust.

4.2. Quality assurance

Another essential public health service is to evaluate and ensure the quality of both personal and population-based health services [13]. Current CCHIT certification criteria and HL7 standards include many items that support monitoring of quality of care at the patient care level; sharing these data could provide important population-level indicators. For example, antibiotic resistance data from individual patients would provide valuable trend data if pooled and analyzed at local, regional, and national levels. Furthermore, some areas of public health concern are not included in standard medical quality assurance; for example, a patient’s access to care, insurance, or a safe environment may be indicators of public health but are not routinely monitored at the point of care.

Data-sharing measures such as those described throughout this review will also enable institution-to-institution health information exchange, which can facilitate locating and consolidating disjointed medical records, in turn supporting patient safety and overall quality of care. New York’s Clinical Information Exchange project (NYCLIX) is an example of a current experiment with health information exchange. The prototype will allow New York City emergency departments to search a database to determine if another city hospital holds records for a current patient; if the patient's records are mentioned in the database, the emergency physician can request access to the electronic file in real time (unpublished description, G. Kuperman and J. Shapiro, 2007).

5. Research

Research is thought to support all three core functions of public health. A public health-oriented EHR system would offer many opportunities for high-quality population-level research by improving data quality, pooling it, and making it available for analysis through traditional epidemiological or data-mining methods. Reliable individual-level health status data could be used to supplement and redesign the major federally funded health surveys [10]. For example, the National Health and Nutrition Survey (NHANES) assesses health status by administering physical exams to volunteers (http://www.cdc.gov/nchs/nhanes.htm), and the National Health Interview Study (NHIS) relies on participant self-report for health status information (http://www.cdc.gov/nchs/nhis.htm); integrating these surveys with individual level clinical record data would change the types of data that would have to be collected from the participant. In addition, an interoperable set of EHR systems could be used to facilitate recruitment for clinical trials. Recruitment currently takes place by reaching out to patients directly through notices and newspaper advertisements or through websites such as ClinicalTrials.gov, by reaching out to their physicians, or by identifying potential candidates through disease registries [10]. EHR systems could be used to help identify patients who meet recruitment criteria, and to facilitate communication between them, their clinicians, and the trial researchers [10]. Depending upon the set-up of the system, patients and providers could either opt in to ask for notifications about clinical trials, or opt out of a default.

6. Conclusion

Expanding EHR systems to support public health will require two types of measures: measures to reuse currently collected data, and measures to collect new types of data. Doing so will entail methodological and other challenges; for example, the privacy, confidentiality, and trust ramifications of putting clinical data to public health uses are critical [10] but outside the scope of this article. Not all of these challenges have clear solutions; a variety of research programs are needed to clarify the issues and develop solutions. It is important to conclude, however, by describing some of the advantages of doing this. For clinicians, a public health-oriented EHR system could reduce the paperwork burden of public health reporting and provide decision support about community-level trends that could aid in diagnosis and treatment choice. Similarly, for institutions, automated reporting would reduce paperwork burdens and data input costs as a trend continues toward more reporting requirements. Automated reporting also has the potential to improve documented adherence to quality assurance criteria. Both industry and NIH-sponsored research groups would benefit from using EHR-collected data to identify, recruit and communicate with potential volunteers for clinical trials. For the public, public health-oriented EHR systems offer increased engagement with the health-care system, more ownership of data, and improved health outcomes. Thus, the incentives for all stakeholders are aligned in improving the public health functionality of EHR systems.

References

[1] Schmitt K, Wofford D. Financial analysis projects clear returns from electronic medical records. Healthc Financ Manage 2002;56:52–7.

[2] Erstad TL. Analyzing computer based patient records: a review of literature. J Healthc Inf Manag 2003;17:51–7.

[3] Bostrom AC, Schafer P, Dontje K, Pohl JM, Nagelkerk J, Cavanagh SJ. Electronic health record: implementation across the Michigan Academic Consortium. Comput Inform Nurs 2006;24:44–52.

[4] Chaudhry B, Wang J, Wu S, Maglione M, Mojica W, Roth E, et al. Systematic review: impact of health information technology on quality, efficiency, and costs of medical care. Ann Intern Med 2006;144:742–52.

[5] Schillinger D, Piette J, Grumbach K, Wang F, Wilson C, Daher C, et al. Closing the loop: physician communication with diabetic patients who have low health literacy. Arch Inter Med 2003;163:83–90.

[6] Stiell A, Forster AJ, Stiell IG, Walraven Cv. Prevalence of information gaps in the emergency department and the effect on patient outcomes. Can Med Assoc J 2003;169:1023–8.

[7] Health and Human Services. Office of the National Coordinator for Health Information Technology; Statement of Organization, Functions, and Delegations of Authority. In: Federal Register; 2005, p. 48718–20.

[8] Poon EG, Blumenthal D, Jaggi T, Honour MM, Bates DW, Kaushal R. Overcoming barriers to adopting and implementing computerized physician order entry systems in U.S. hospitals. Health Aff 2004;23:184–90.

[9] Ford EW, Menachemi N, Phillips MT. Predicting the adoption of electronic health records by physicians: when will health care be paperless? J Am Med Inform Assoc 2006;13:106–12.

[10] Rippen HE, Yasnoff WA. The electronic health records system in population health. In: Lehmann HP, Abbott PA, Roderer NK, Rothschild A, Mandell SF, Ferrer JA, Miller RE, Ball MJ, editors. Aspects of electronic health record systems. New York, London: Springer; 2006.

[11] Koontz LD, Powner DA. Health information technology: early efforts initiated but comprehensive privacy approach needed for national strategy. In: General Accountability Office GAO-07-400T; February 1; 2007.

[12] Pear R. Warnings over privacy of U.S. health network. The New York Times; February 18; 2007.

[13] Institute of Medicine. The Future of Public Health. Washington, DC: National Academy of Sciences; 1988.

[14] Institute of Medicine. The Future of the Public's Health in the 21st Century. Washington, DC: National Academy of Sciences; 2002.

[15] Mon DT. The difference between the EHR standard and certification. J Ahima 2006;77:66–70.

[16] Health Level Seven—HL7 Electronic Health Record (EHR) Technical Committee's Home Page. Available from: http://www.hl7.org/ehr/.

[17] Certification Commission for Health Information Technology—Preparing for CCHIT Certification Page. Available from: http://www.cchit.org.

[18] Institute of Medicine. Secret Agents: The Menace of Emerging Infections. National Academy of Sciences; 2002.

[19] The Markle Foundation. Connecting for Health: A Public-Private Collaborative: The Markle Foundation; 2003.

[20] Chute CG, Koo D. Public health, data standards, and vocabulary: crucial infrastructure for reliable public health surveillance. J Public Health Manag Pract 2002;8.

[21] Hripcsak G, Bakken S, Stetson PD, Patel VL. Mining complex clinical data for patient safety research: a framework for event discovery. J Biomed Inform 2003;36:120–30.

[22] Tsui F-C, Espino JU, Dato VM, Gesteland PH, Hutman JW, Michael M. Technical description of RODS: a real-time public health surveillance system. J Am Med Inform Assoc 2003;10:399–408.

[23] Loonsk JW, McGarvey SR, Conn LA, Johnson J. The Public Health Information Network (PHIN) preparedness initiative. J Am Med Inform Assoc 2006;13:1–4.

[24] Marx M, Rodriguez C, Greenko J, Das D, Heffernan R, Karpati A, et al. Diarrheal illness detected through syndromic surveillance after a massive power outage: New York City, August 2003. Am J Public Health 2006;96:547–53.

[25] Public Health Data Standards Consortium. Electronic Health Record: Public Health Perspectives. Baltimore, MD: Public Health Data Standards Consortium; 2004.

[26] Alpi K. Expert searching in public health. J Med Libr Assoc 2005;93:97–103.

[27] Public Health Conceptual Data Model: Premier Edition. Atlanta, Georgia U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention (CDC); 2000.

[28] Yasnoff W, Overhage J, Humphreys B, LaVenture M. A national agenda for public health informatics: summarized recommendations from the 2001 AMIA Spring Congress. J Am Med Inform Assoc 2001;8:535–45.

[29] Ventres W, Kooienga S, Vuckovic N, Marlin R, Nygren P, Stewart V. Physicians, Patients, and the Electronic Health Record: An Ethnographic Analysis; 2000, p. 124–31.

[30] Biosurveillance Technical Committee. Standards gap and overlap analysis biosurveillance use case: visit, utilization, and lab results data. In: Office of the National Health Information Technology Coordinator, editor. Evaluation of Standards Harmonization Process for HIT: Healthcare Information Technology Standards Panel; 2006.

[31] Biosurveillance Technical Committee. Selected standards. In: Office of the National Health Information Technology Coordinator, editor. Evaluation of Standards Harmonization Process for HIT: Healthcare Information Technology Standards Panel; 2006.

[32] Anderson N. Levels of analysis in health science. A framework for integrating sociobehavioral and biomedical research. Ann NY Acad Sci 1998;840:563–76.

[33] Wagner. Chronic disease management: what will it take to improve care for chronic illness? Effective Clinic Pract 1998;1.

[34] University of Texas at Austin SoN, Family Nurse Practitioner Program. Screening for metabolic syndrome in adults. Austin (TX): University of Texas at Austin, School of Nursing; l2004.

[35] Tsui F-C, Espino JU, Dato VM, Gesteland PH, Hutman J, Wagner MM. Technical Description of RODS: A Real-time Public Health Surveillance System. In: 2003, p. 399–408.

[36] Gesteland PH, Gardner RM, Tsui F-C, Espino JU, Rolfs RT, James BC et al. Automated Syndromic Surveillance for the 2002 Winter Olympics. In: 2003, p. 547–54.

[37] Hiatt RA, Rimer, Barbara K. A new strategy for cancer control research. Cancer Epidemiol Biomarkers Prev 1999;8:957–64.

[38] Fine AM, Nigrovic L, Reis BY, Cook EF, Mandl KD. Linking surveillance to action: Incorporation of real-time regional data into a medical decision rule. J Am Med Inform Assoc 2007. epub ahead of print (January).

[39] Peabody J, Luck J, Jain S, Bertenthal D, Glassman P. Assessing the accuracy of administrative data in health information systems. Med Care 2004;42:1066–72.

[40] Hripcsak G, Knirsch CA, Jain NL, Pablos-Mendez A. Automated tuberculosis detection. J Am Med Inform Assoc 1997;4:376–81.

[41] Chapman WW, Cooper GF, Hanbury P, Chapman BE, Harrison LH, Wagner MM. Creating a text classifier to detect radiology reports describing mediastinal findings associated with inhalational anthrax and other disorders. J Am Med Inform Assoc 2003;10:494–503.

[42] Garrett NY, Yasnoff WA. Disseminating public health practice guidelines in electronic medical record systems. J Public Health Manag Pract 2002;8:1–10.

[43] Whitelaw G, Vaughan H, Craig B, Atkinson D. Establishing the Canadian Community Monitoring Network. Environ Monit Assess 2003;88:409–18.

[44] Solet D, Glusker A, Laurent A, Yu T. Innovations in user-defined analysis: dynamic grouping and customized user datasets in VistaPHw. J Public Health Manag Pract 2006;12:130–8.

[45] Friedman D, Parrish Rn. Characteristics, desired functionalities, and datasets of state Web-based Data Query Systems. J Public Health Manag Pract 2006;12:119–29.

[46] Speros C. Health literacy: concept analysis. J Adv Nurs 2004;50:633–40.

[47] Yasnoff WA, Overhage JM, Humphreys BL, LaVenture M. A National Agenda for Public Health Informatics: Summarized Recommendations from the 2001 AMIA Spring Congress; 2001, p. 535–45.

[48] Ash JS, Berg M, Coiera E. Some unintended consequences of information technology in health care: the nature of patient care information system-related errors. J Am Med Inform Assoc 2004;11:104–12.

[49] Williams MV, Davis T, Parker RM, Weiss BD. The role of health literacy in patient-physician communication. Family Med 2002;34:383–9.

[50] Everson-Rose S, Lewis T. Psychosocial factors and cardiovascular diseases. Ann Rev Public Health 2005;26:469–500.

[51] Lorig K. Self-management of chronic illness: a model for the future. Generations 1993;17:11–4.

[52] McDonnell Norms Group. Enhancing the use of clinical guidelines: a social norms perspective. J Am Coll Surg 2006;826–36.

[53] National Guidelines Clearinghouse. Screening for metabolic syndrome in adults.

[54] Staroselsky M, Volk LA, Tsurikova R, Pizziferri L, Lippincott M, Wald J, et al. Improving electronic health record (EHR) accuracy and increasing compliance with health maintenance clinical guidelines through patient access and input. Int J Med Inform 2006;75:693–700.

[55] Cimino J, Li J, Mendonca E, Sengupta S, Patel V, Kushniruk A. An evaluation of patient access to their electronic medical records via the World Wide Web. Proc AMIA Ann Symp 2000:151–5.

[56] Cimino J, Patel V, Kushniruk A. The patient clinical information system (PatCIS): technical solutions for and experience with giving patients access to their electronic medical records. Int J Med Inform 2002;68:113–27.

[57] Baorto D, Cimino J. An ''infobutton'' for enabling patients to interpret on-line Pap smear reports. Proc AMIA Ann Symp 2000:47–50.

[58] DeNavas-Walt C, Proctor B, Lee CH. Income, Poverty, and Health Insurance Coverage in the United States: 2004. Washington, DC: U.S. Census Bureau; 2005.

[59] Institute of Medicine. Care Without Coverage—Too Little, Too Late. Washington, DC: The National Academies Press; 2002.

[60] Grossman JM, Reed MC. Most medicare outpatient visits are to physicians with limited clinical information technology. Data Bull (Center for Studying Health System Change) 2005;30:1–4.

[61] Reed MC. Why people change their health care providers. Data Bull (Center for Studying Health System Change) 2000;16:1–2.