Proactive Population Health Management in the Context of a Regional Health Information Exchange Using Standards-Based Decision Support

David F. Lobach, MD, PhD, MS1; Kensaku Kawamoto, PhD1; Kevin J. Anstrom, PhD2; Kevin R. Kooy, ME1; Eric L. Eisenstein, DBA3; Garry M. Silvey, BS1; Janese M. Willis, MS, MBA1; Frederick Johnson, MBA1; and Jessica Simo, MHA1
1Department of Community and Family Medicine, 2Department of Biostatistics and Bioinformatics, and 3Department of Medicine, Duke University Medical Center, Durham, NC

ABSTRACT
The clinic-based healthcare model does not deliver high quality, cost-effective care to populations of patients. Despite public perception that aggressive investment in information technology will lead to improvements in the safety and quality of healthcare delivery, there is little evidence that health information technology can be used to promote population-based health management. This paper describes the use of a standards-based clinical decision support system to facilitate proactive population health management using data from a regional health information exchange (HIE) network. The initial release of this system was designed to detect ten sentinel health events related to hospitalization, emergency department (ED) utilization, and care coordination in a population of 36,000 individuals. In an analysis of 11,899 continuously enrolled patients from a single county over a six-month period, 2,285 unique patients experienced 7,226 sentinel health events. The most common events were ED utilization for low severity conditions (2,546), two or more missed appointments within a 60-day period (1,728), ED encounters for patients with asthma (1,220), and three or more ED encounters within 90 days (731). Logistic regression analysis identified patients aged 19-64 as the population most likely to have sentinel health events. In addition to presenting data demonstrating the feasibility of population health management using a regional health information exchange (HIE), this paper also includes lessons learned from the development, implementation, and operational support of the population health management system.

INTRODUCTION
Conventional models of clinic-based healthcare delivery have failed to provide consistent, high-quality care across entire populations. Such models promote crisis-oriented care and serve only individuals who seek assistance by going to a clinic site. New population-oriented care models are emerging that seek to provide care for patients not presenting to an outpatient site. Information technology has been identified as a critical element for supporting such new models and for reducing errors and improving quality. Information technology, and in particular a health information exchange (HIE), has the capacity to enhance the management of the health of populations by promoting the sharing of health information across independent healthcare organizations. The information available through HIEs can be used by clinical decision support (CDS) systems to identify sentinel health events and patient-specific care needs, and then to promote proactive interventions.

Relatively little has been published regarding the role of health information technology in population health management. Previous studies have shown that population-based care management programs focusing on potentially high risk patients can reduce costs and improve outcomes. These studies did not rely on health information technology to facilitate the identification of patients in need of care management and showed only modest improvements. In 2005, Javitt et al. reported that alerts to physicians that identify errors and promote best practices reduced hospitalizations and costs. These alerts were generated through a claims-based surveillance system for commercially insured patients. Involvement of nurses in the alerting process through interactions with patients and physicians increased the identification and resolution of concerning clinical issues. These studies, however, focused solely on patients and data from within a single private health insurance program.

In this paper, we describe an information-based, population-oriented care model that draws upon information from a regional HIE to provide proactive care management to Medicaid beneficiaries using a standards-based approach to clinical decision support. We provide data regarding the frequency of sentinel health events detected within this population and use logistic regression models to identify patient characteristics that are associated with each specific event type. We also discuss the challenges we encountered and lessons learned in developing and supporting proactive population health management.
METHODS

Population-based Care Management

In 1997, the North Carolina Department of Medical Assistance instituted a demonstration project to provide care management for Medicaid beneficiaries in Durham County, North Carolina. This single-county care management program was expanded in 2001 to add four adjacent counties leading to the formation of a partnership known as the Northern Piedmont Community Care Network (NPCCN). This partnership currently includes 32 private practices, three federally qualified health centers, four community hospitals, nine government agencies (county health departments and departments of social services), one academic medical center, and two care management teams.

The two community-based care management teams are each led by a program manager and include nurses, social workers, community health workers, nutritionists, and health educators. Approximately 1,000 individuals are under active care management at any time. Care management services offered through the Network include home assessments, in-home health education and dietary instruction, assistance keeping scheduled clinic appointments, and support for obtaining and taking medications. Furthermore, these providers routinely interact with other network partners including physicians, nurse practitioners, nurses, and pharmacists.

Development of a Regional HIE

In an effort to support such community-based care management, a regional Health Information Exchange (HIE) network was developed. The COACH system (Community-Oriented Approach to Coordinated Healthcare) was initiated in 2000 as a care management documentation tool. Over the ensuing seven years, the system has been enhanced to facilitate communication between team members collaborating in the care of patients in the Network.

COACH was built on a Web-based platform using Notes Domino (www.lotus.com) to facilitate access to the system by all partners. The data in COACH are stored in a central Microsoft SQL Server database that serves as a shared data repository for all the partner organizations participating in the HIE network. COACH is partitioned into multiple individual “silos” that contain patient records for specific programs. In compliance with HIPAA, users are given access only to data in their programs. Secondary uses of the data, such as for report generation and CDS, are conducted using a synchronized replica of the COACH database.

Basic demographic and eligibility data for Network enrollees are uploaded to the system from the North Carolina Office of Rural Health and Community Care on a monthly basis, and data transfer protocols are in place to import clinical and billing data from partner sites. The four types of data collected by the system include: 1) administrative (demographics and identifiers, services used, provider associations, audit trails); 2) care management (care management encounters, health risk and environment assessment, socio-economic data, special needs, and care management plans); 3) clinical (encounters, problems/procedures, missed appointments, medications, allergies, laboratory results, disease-specific care plans); and 4) communication (messages and alerts, referrals, notices of new information).

COACH HIE Network Data Imports

Compiling patient data from multiple sources to create the COACH HIE data repository is one of the system’s greatest strengths as well as one of its biggest operational challenges. To match data from multiple sites for a single patient, we have created the equivalent of an enterprise master patient index (EMPI) within the COACH system. The COACH EMPI is a registry containing all of the available medical record numbers and program enrollment numbers (e.g., Medicaid IDs) for a given individual. Data coming from a partner site must match one of these numbers in order to be added to a patient’s record in COACH. Secure XML-based data transfer protocols are used to import data from provider organizations. The imported data include encounter and pharmacy claims data from the State Medicaid Office, as well as billing data from nine clinics and all five hospitals in the service region. The billing data received from provider organizations can overlap with the State encounter claims data; however, we chose to obtain the billing data directly from the provider organizations when possible, as the state-provided data can be delayed by the need for payment processing, and as some claims are denied and therefore appear only in the provider billing data.

Identification of Sentinel Health Events

We worked with the medical directors and administrators for the primary care clinics participating in the network and with members of the care management team to define and prioritize sentinel health events that would benefit from care management. Sentinel events were defined as resource utilization by patients (events of commission) that were considered excessive (e.g., three ED visits in 90 days) or potentially avoidable (e.g., ED visit for asthma) and that could potentially be modified by the involvement of care managers and other providers. Prioritization was empirically derived so that issues of greatest importance to the care management team such as ED and hospital resource use received the greatest weight.
Integration of Standards-Based CDS in Population Health Management

The COACH HIE network has been adapted to use a standards-based decision support service known as SEBASTIAN (System for Evidence-Based Advice through Simultaneous Transaction with an Intelligent Agent across a Network) to support sophisticated population health management activities within the network. SEBASTIAN is a framework for encapsulating a core component of CDS applications, namely the component that evaluates patient data and generates patient-specific conclusions, into an application-independent service. SEBASTIAN is also serving as the basis of an international draft standard for CDS known as the HL7 Decision Support Service (DSS) standard, which was formally adopted as a draft standard in September 2006.

Implementation of Population Health Management

SEBASTIAN is currently being used to support population health management in the COACH HIE network. First introduced four years ago, SEBASTIAN is now in production-level use to provide population health management for over 36,000 Medicaid beneficiaries in the COACH HIE network. The demographic characteristics of this population are summarized in Table 1. The COACH population health management module uses rule-based knowledge modules to detect such care issues as inappropriate resource utilization and patient-reported barriers to accessing care services. The care issues identified by SEBASTIAN are prioritized and then distributed as alerts to care managers, as feedback reports to clinic managers, and as care reminder letters to patients or their guardians in cases involving minors.

The impact of these notices on care quality, utilization, coordination, and costs is under evaluation in a randomized controlled trial.

Data Management and Analysis

The population health management system records, at the level of the individual patient, every sentinel health event that is detected from a patient's data in the COACH HIE. The number of sentinel health events for the six-month period from September 2006 to February 2007 was extracted from the event recording database along with patient characteristics including date of birth, gender, race/ethnicity, number of family members in Medicaid, and clinic assignment. For the information reported in this report, we focused on the Medicaid patients from Durham County who had been continuously enrolled in Medicaid for the six-month evaluation period. We elected to monitor only continuously enrolled patients because we wanted to have the complete dataset of all of the care provided to the individuals included in the analysis. We focused on patients from Durham County, because data are available from six of the eight primary care clinics in Durham County, representing the primary care clinic sites where more than 95% of the Durham County Medicaid beneficiaries are assigned for care.

As an exploratory analysis, we sought to identify patient characteristics that would be predictive of generating a sentinel event. Comparisons of characteristics between the patients receiving and not receiving specific notifications were done using chi-square statistics. Multivariable logistic regression models were constructed to determine which patient characteristics were associated with the common notifications.

This study was approved by the Duke University School of Medicine Institutional Review Board.

## RESULTS

### Status of the HIE

Through data imported from partner organizations, COACH currently contains records on 88,731 unique patients (36,387 active); 1,169,195 healthcare encounters; 79,476 care management encounters (e.g. home visits); 63,285 missed appointments; 1,867,824 billing diagnoses; 2,205,386 billing procedures; 4,492 laboratory results; and 1,286,314 pharmacy claims.

### Detection of Sentinel Health Events

For the six-month period from September 2006 through February 2007, 11,899 patients were continuously enrolled in Medicaid in Durham County. Out of this population, 7,226 sentinel health events were detected for 2,285 unique patients (19.3% of the total population). The range of alerts for individual patients was zero to 43. The frequency with which each sentinel health event was identified is summarized in Table 2 (next page).

### Association of Patient Characteristics with Sentinel Health Events

In Table 1, the characteristics of the overall NPCCN population are compared with the subset receiving at least one notification in the 6-month
period. Patients between ages 19 and 64 were much more likely to be in the subset of patients receiving notifications. The results of the logistic regression models support these findings (Table 3). For all endpoints, patients aged 19-64 were much more likely to have sentinel health events. For the model predicting 2 or more missed appointments, those patients aged 19-64 were between 2 and 5 times more likely to have sentinel health events. For the same endpoint, Hispanics were approximately 40% less likely to have sentinel health events. For the model endpoints, patients aged 19-64 were much more likely to be in the subset of patients receiving notifications. The results of the logistic regression models demonstrated that we can detect important care needs of a population. Specifically, we detected 7,226 sentinel health events in 2,285 unique individuals over a six-month period. This work builds upon previous publications in that data from a HIE was used to facilitate care management.

We have learned several valuable lessons through the development, implementation and operational support of this population health management system. In the area of system development, we have discovered that resolving political issues related to the exchange of clinical information and identifying resources to implement the data exchange are often more challenging and time consuming than the technical aspects of information exchange. We also noticed, however, that once the exchanged information was in use for proactive care management, clinical sites began to offer their information to the HIE so that they could reap the benefits of the proactive care notices. As we began to implement the proactive notification rules, we detected two distinct types of events requiring follow-up: events of commission (e.g., ED encounters) and events of omission (e.g., missing preventive care services). We also discovered that components of knowledge could be reused across rule sets, e.g., a rule for determining if a patient has diabetes was useful for both notices for hospitalization and notices for ED utilization. Finally, with regard to development, we observed that the perceived value of the generated notices to the recipients was dependent on the timeliness and completeness of the underlying HIE dataset. Notices had the greatest the value if they were proximal to the event and highly accurate. This observation

<table>
<thead>
<tr>
<th>Category</th>
<th>Target Group</th>
<th>Message Focus and Content</th>
<th># of Notices</th>
</tr>
</thead>
<tbody>
<tr>
<td>ED Encounters</td>
<td>Aged 0 to 20</td>
<td>ED encounter in the past month with fever as the primary diagnosis</td>
<td>457</td>
</tr>
<tr>
<td>ED Encounters</td>
<td>Women</td>
<td>ED encounter in the past month with a pregnancy-related issue as the primary diagnosis</td>
<td>29</td>
</tr>
<tr>
<td>3+ ED in 90 days</td>
<td>All</td>
<td>ED encounter in past month that constituted the 3rd or greater ED encounter in 90 days</td>
<td>731</td>
</tr>
<tr>
<td>Low-severity ED</td>
<td>All</td>
<td>Low-severity ED encounter in the past month. Low-severity ED encounters are deemed to have occurred if one of the following conditions hold: (1) patient had an evaluation and management CPT procedure code indicative of a low-severity ED visit, or (2) there are no encounter diagnoses deemed to be medium-to-high severity by NC Medicaid</td>
<td>2,546</td>
</tr>
</tbody>
</table>

Table 3. Logistic Regression Results

<table>
<thead>
<tr>
<th>Patient Factors</th>
<th>Any Alert</th>
<th>Low Severity ED</th>
<th>3+ ED visits in 90 days</th>
<th>Missing 2+ appts in 60 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age 0-5</td>
<td>0.59*</td>
<td>0.81*</td>
<td>0.19*</td>
<td>0.45*</td>
</tr>
<tr>
<td>Age 6-12</td>
<td>0.30*</td>
<td>0.35*</td>
<td>0.08*</td>
<td>0.22*</td>
</tr>
<tr>
<td>Age 13-18</td>
<td>0.36*</td>
<td>0.39*</td>
<td>0.21*</td>
<td>0.30*</td>
</tr>
<tr>
<td>Age 65+</td>
<td>0.48*</td>
<td>0.32*</td>
<td>0.26*</td>
<td>0.15*</td>
</tr>
<tr>
<td>Black</td>
<td>1.12</td>
<td>1.15</td>
<td>1.09</td>
<td>1.04</td>
</tr>
<tr>
<td>Hispanic</td>
<td>0.81</td>
<td>0.94</td>
<td>0.65</td>
<td>0.59*</td>
</tr>
<tr>
<td>Female</td>
<td>1.07</td>
<td>1.10</td>
<td>1.18</td>
<td>1.09</td>
</tr>
</tbody>
</table>

Numbers shown are the odds ratios for notification; *P<0.01; age reference group: 19-64 year old patients

**DISCUSSION**

In this project, we have developed and implemented an approach for proactive population-oriented health care management using standards-based decision support in the context of a regional health information exchange for Medicaid beneficiaries. Through this system, we have demonstrated that we can detect important care needs of a population. Specifically, we detected 7,226 sentinel health events in 2,285 unique individuals over a six-month period. This work builds upon previous publications in that data from a HIE was used to facilitate care management.
compelled us to obtain billing data directly from clinic sites within 24 to 72 hours after an event, rather than relying on processed claims data that could be several months old.

With regard to system implementation, we have observed that asynchronous population health management is complex. In a real-world setting, it is often difficult to determine who should be notified about sentinel health events for a specific patient. It is often unclear which providers are assigned to a specific individual, and providers frequently change. We have concluded that enabling system users to designate to whom a specific notice should be distributed is preferred over automated distribution. Another level of complexity was how frequently notices should be re-sent. For events of commission, we routinely sent only one notice immediately following the event. A third challenge with implementation was determining how to prioritize the order of notices sent to care managers. Ultimately, we empirically developed a prioritization scheme that resulted in the most concerning issues appearing on the top of the weekly notification lists. We also empirically selected a cut off of 25 notices per care manager per week.

From our experience supporting the system operationally, we learned that an increased amount of available information promotes increased use of the system. Additionally, as users became increasingly dependent on the notification system, they restructured their work practices to allow the system to direct their care management activities.

The findings of this study are limited in that the care management activities have focused on Medicaid beneficiaries, which may restrict the applicability of our findings to other populations. A second limitation is that our population health management system has relied heavily on care managers. Our approach can be used in other settings provided that recipients can be identified who will respond to the notices. A third limitation is that our system has functioned primarily off of billing/claims data as opposed to clinical data from an electronic health record system. This approach represents a minimalist view of what could be possible in terms of population health management if a more comprehensive clinical dataset were available. As the breadth of clinical data available in HIEs increases, the value of proactive population health management is also likely to increase.

**CONCLUSION**

New approaches to care delivery are needed to improve health care quality and the coordination of services across populations. CDS can be used in the context of a regional HIE in order to promote proactive population health management. Through this study, we have shown that sentinel health events can be identified from billing/claims data and clinical data. Further research is in progress to determine the impact of this information technology-based approach on care quality and costs.

**ACKNOWLEDGEMENTS**

This study was funded in part by R01 HS-015057 from the Agency for Healthcare Research and Quality and by H2ATH00998 from the Office for the Advancement of Telehealth of the Health Resources and Services Administration.

**REFERENCES**


AMIA 2007 Symposium Proceedings Page - 477