Framework for Evaluating Electronic Health Records
Davies Recognition Program
Davies Public Health Award of Excellence
Denver Public Health, Denver Health - Application

Section A.

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8. Description of communities/ populations served	Denver County and Denver Metro region
9. Number of FTEs:	
a. Entire organization	146.5
• Physicians	12.6
• Nurses	29.8
• Program managers	18.0
• Clinical/front line staff	72.1
• Administrative	8.0
• Informatics	4.0
• Preparedness	2.0
b. Directly involved in submission project	4
10. Description of public health program(s) directly affected by submission	Communicable diseases and sexually transmitted diseases
11. Names of Electronic Public Health Information Team members	Arthur Davidson, Dean McEwen, Cornelis Rietmeijer, Judith Shlay, Christopher Urbina

The Organization

Denver Public Health (DPH) is a division within Denver Health and Hospital Authority (DH), a vertically integrated, safety-net health care provider. In addition to public health services, DH consists of community health centers, a health plan, substance treatment services, correctional care, school-based clinics,, poison control center, an emergency medical system, and an academic level-1 trauma center and 500 bed hospital, and (see Figure 1). DH cares for nearly 25% of Denver's 600,000 citizens every year, but DPH also serves the broader Denver Metro region. There is an integrated electronic health record across this personal health care continuum, but neither public health surveillance nor sexually transmitted disease (STD) clinical services is included. As part of the 10 essential public health services[1], DPH has provided STD (17,000 visits/year), tuberculosis(15,000 visits/year), infectious diseases (14,000 visits/year), and immunization clinical services (22,000 immunizations/year) for decades to many residents in the broader 7-county Denver Metro region which includes more than 2.75 million people. DPH cares for 75% of all active tuberculosis cases and has worked to collaboratively solve information flows and interface with the Colorado Department of Public Health and Environment around communicable disease reporting for more than 10 years.

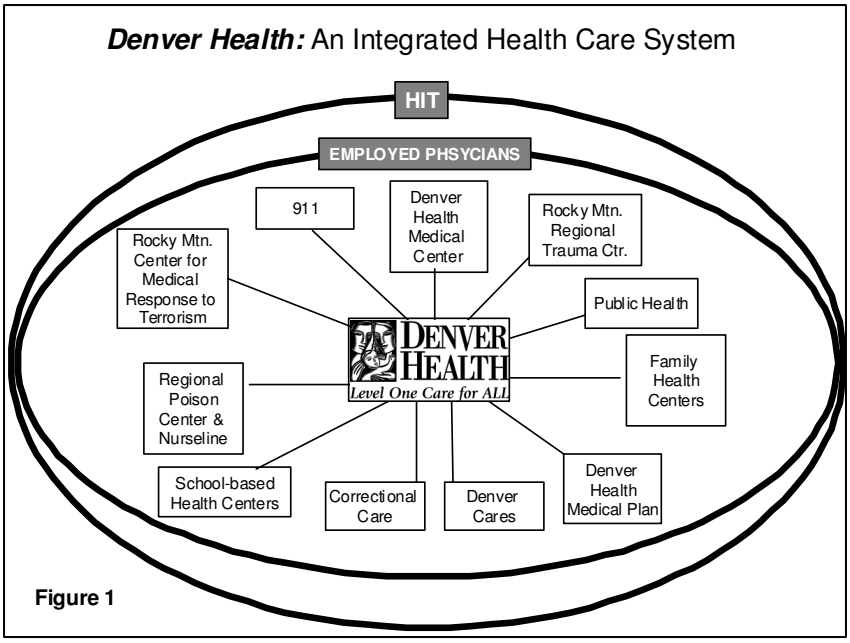


Figure 1

DPH mission: "*In partnership with Denver's diverse communities, Denver Public Health promotes, improves and protects the population's health through disease prevention and health promotion activities, direct clinical care, and other health services*".

Through Denver Health (DH), an independent governmental authority since 1997, the City and County of Denver contracts with DPH to provide essential public health services. DH has worked to become an efficient and lean organization serving most of Denver's under or uninsured with a predominance of Latino (75%) patients. Offering sliding scale payment, DH diagnostically-related groups (DRG) charges are typically lower on average than market peers. This efficient, single administration system offers multiple services in an environment where all physicians are employed (without any incentive plan) and foundationally supported by a sophisticated information infrastructure. Providing information at point of care reduces duplications and inefficiencies and gets the right information to the right provider at the right time to promote the right care.

The unique relationship between the public and personal health service environments within DH has been paramount for successful implementation and effective utilization of the

information systems to be described. While DPH is the applicant, the context for that organization, as a component of DH where public health services leverage information systems, informatics expertise, and the information contained within personal health care systems is unique. The knowledge and expertise of many systems (and their custodians) are collaboratively linked to benefit the larger public health system. Patient transitions of care are common between public and personal health care, thus the focus of DH is to assure that populations served are the beneficiaries of highly integrated services. In addition, aggregated analyses permit broad assessment of safety-net and population-based services on communities rather than specific individuals.

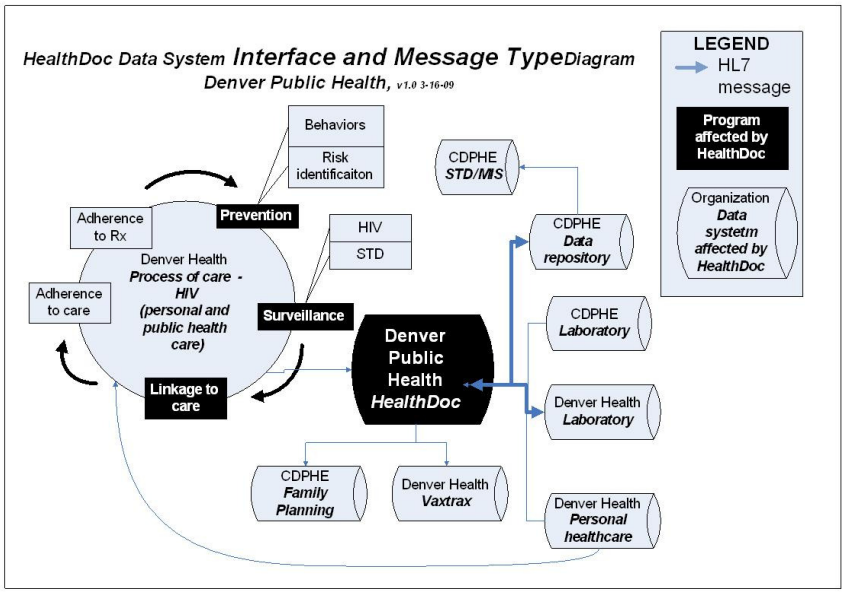
Project Objectives

With the investment in HealthDoc, an electronic health record (EHR) or the STD clinic, DPH hoped to accomplish the following:

- reduce clerical activities and manual data exchange processes,
- increase clinician access to evidence-based protocols at the point of care,
- support the rapid exchange of valuable surveillance data ,
- support research efforts,
- apply decision support, and
- reuse data for essential public health functions.

Automated electronic exchange should reduce human costs in managing data, while affording quality improvement opportunities. A phased approach would help achieve the overarching goal of eliminating unnecessary forms and reports, build bi-directional reporting, and improve local and state health department productivity. DPH expected to redirect resources from paper-driven clerical processes to enhance clinical care by building flexible tools for data collection and feedback loops to providers. In addition, the system would provide ready access to population level data and interface with other disease control programs. The working environment would need to change; DPH anticipated a need to build a technologically savvy clinician program that recruited and retained staff interested in working on a new EHR platform.

Figure 2.



HealthDoc, the data collection system, is a comprehensive electronic patient encounter questionnaire with interactive protocol-driven logic based on patient responses, known epidemiologic patterns, and clinical results. However, the HealthDoc application extends to many other public health care and program areas, associated information

systems, and partners. HealthDoc encompasses a centralized data repository offering interoperability among clinical departments and transparent data usability (see Figure 2). HealthDoc also offers advanced reporting capabilities for internal use and external data dissemination for local, state, and national agencies.

For more than four decades, DPH has been the source for clinical, disease control and surveillance services in the City and County of Denver. Using clinical systems to support surveillance activities through health information exchange has been an ongoing effort [2]. With the internet and capacities for interoperability, potential efficiencies have been realized at the interface of public and personal health systems. For instance, in the early years of its sexually transmitted diseases (STD) control program, DPH built a protocol-driven system to collect data on paper forms. Monthly, these forms were bundled and reviewed to generate summaries using tick marks to track disease, gender, age, race and sexual preference.

In the mid-1980's, as personal computers entered the clinic, a scannable clinic form and a scanning device were used to more efficiently collect these data and permit rudimentary clinical decision support to improve both data quality and clinical services. However, most of the painful, tedious paper processes were still being used for both clinical and surveillance activities.

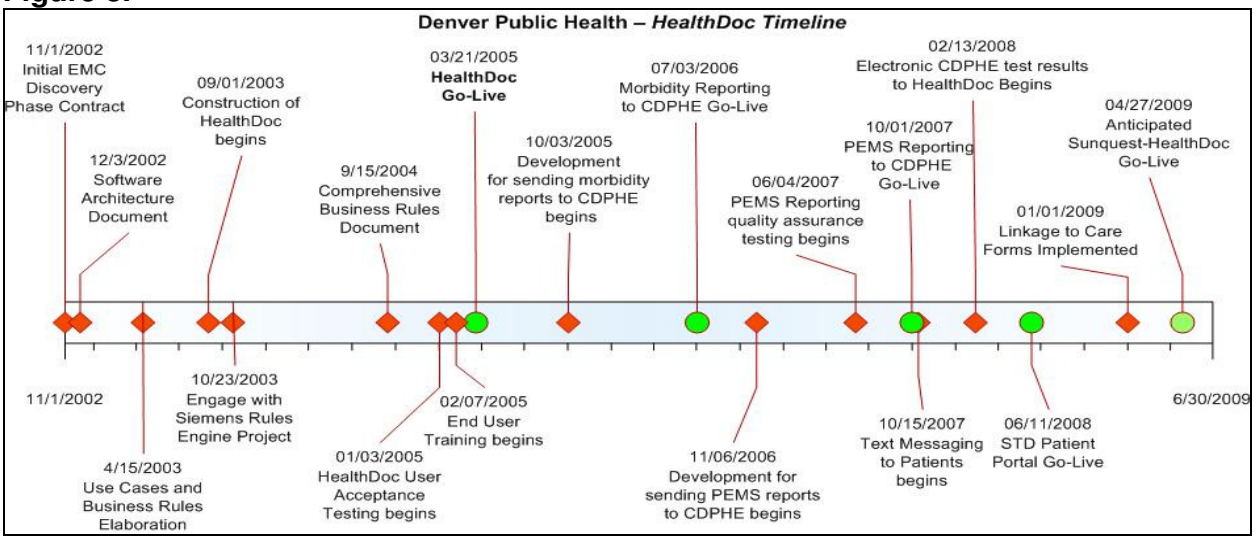
By 2002, DPH envisioned a more robust, efficient, web-based EHR that cost-effectively guided clinicians and other end-users to provide more comprehensive services while directly connecting data to surveillance systems. Various individuals (e.g., patients, clinicians, clerks. laboratorians, epidemiologists and disease control interventionists) all required access to the same data, repurposed for their specific needs and tasks. With efficient workflow tools, information could be entered and accessed immediately rather than waiting for paper forms and logs to be completed, processed, and verified; this would improve the timeliness, completeness, and efficiency of surveillance systems. In addition, as new services or surveillance needs were identified and implemented, data structures (e.g., collection forms and variables) should flexibly incorporate quality improvement cycles rather than be constrained by limited data collection "real-estate". Cryptic scan forms were cumbersome to complete, limited in scope, and extremely inflexible as new data or information were needed. A flexible, interoperable, and transparent system that promoted authorized data access was the targeted outcome.

Project Organization

Effective health information exchange between this EHR and surveillance systems would not have been possible without extensive coordinated efforts with the larger DH agency where a public health department uniquely benefits from an integrated delivery system. Prior to this time, typical DPH information system development was initiated in-house, in a local area network, independent from DH. With coordinated DPH - DH eHealth Services (DH-eHS) effort, a change approach benefited from and integrated expertise from both public and personal health care worlds. DPH engaged DH-eHS project management resources to support HealthDoc development. With a consulting group (EMC), business analysts carefully documented the entire work flow and created detailed use cases for each of end-user group (i.e., clinicians, laboratorians, surveillance personnel, epidemiologists, and clerks). Since interfaces with multiple other systems (e.g., Siemens, Sunquest, and state information systems) were needed, DPH engaged these individuals to help develop a

cohesive work plan. As project management was initiated, some of the objectives needed to be staged to allow a timely and fiscally constrained roll-out, while preserving enhancements for later stages (See Figure 3). While building HealthDoc (the EHR), the project needed aggressive management to control cost and scope. Total funds expended were approximately $500,000 but early requirements gathering, business process analysis, and prototype development resulted in a faster consumption of limited resources than anticipated. HealthDoc was to be used by approximately 20 clinicians, several laboratorians, attending physicians, data analysts, researchers, and program managers simultaneously with 3-6 interfaces with other computer systems.

Figure 3.



All these system stakeholders were included in requirements analysis. A project team consisting of informaticians, clinicians, project managers, analysts and software developers met regularly to monitor the project, progress, change requests and resources. As specific new interfaces were being designed and developed, those interested stakeholders were included in project planning.

Project Implementation

Roles, Responsibilities and Timelines

Clinicians need a friendly EHR that supports documentation while encouraging protocol-driven, evidence-based care. While the STD program wants clinicians to see more patients and assure quality care, the organization's mission is to address all essential public health services, by using information to support more timely interventions. Foremost, accurate monitoring of disease occurrence and spread are core surveillance functions and fundamental for disease control.

This project started with a point of care clinical documentation tool (HealthDoc), to address clinician and patient needs; gathered information then serves multiple functions. Information generated from HealthDoc provides a monthly summary to the Epidemiology and Surveillance Units. Data are aggregated and reported for clinic activity and then compared with reports to the Colorado Electronic Disease Reporting System (CEDRS) and Sexually Transmitted Diseases Management Information System (STD/MIS). Disease control specialists conduct intervention efforts for individuals not returning for care, and to

inform identified sexual partners regarding need for prophylaxis, to avoid ongoing disease spread throughout the population. For the past 4 years, 100% of 20 clinicians (and 12 attending physicians) in the STD clinic have used this system for 100% of the patients seen. This provides a comprehensive database to support the surveillance and research activities.

HIV prevention services had traditionally been physically and programmatically separate from the STD clinic. In the past decade, though, there has been a growing effort to better integrate STD and HIV prevention services, both nationally and internationally. HealthDoc allowed us to reorganize these services at DPH and allow for HIV prevention activities to be fully integrated in the course of STD care, at minimal additional expense. Furthermore, HIV and STD prevention outreach efforts have been bolstered by availability of rapid and non-invasive HIV and STD testing methods; in the past decade, DPH has capitalized on these developments by offering services in a variety of outreach settings, including HIV testing in bath houses, and chlamydia and gonorrhea testing in schools, detention facilities, and community-based organizations. Previously, service documentation was maintained in separate databases; the new system allowed DPH to seamlessly integrate all STD and HIV service data. This integration enhanced capability to cross-reference individual patient records from different service delivery sites and comprehensively aggregate DPH data for all STD and HIV prevention services.

For patients identified with HIV infection, data from the clinical system are used to inform outreach workers and to monitor for adequate linkage to care. As a result, nearly 100% of all new HIV positive clients are linked to a health care provider. Since HealthDoc implementation, a feedback loop permits surveillance staff to coordinate activities with clinical services to assure that infected individuals are properly enrolled in treatment. HIV-infected individuals are monitored not only through linkage to care, but surveillance data supports efforts to assure adherence to care, adherence to antiviral regimens and monitoring for new incident cases of opportunistic infections through matching surveillance data to personal health care information systems that contain the latest opportunistic infection events, CD4, and viral load counts. Linkage and adherence to care are the most effective ways to diminish ongoing HIV infection spread through at-risk populations; by promoting prevention messages at every clinical or community opportunity (e.g., sending outreach workers to patient homes), public health can reduce risk of spread by encouraging clinical follow up, safe behaviors, and monitoring adherence to medication.

As HealthDoc was implemented, opportunities to improve population services were identified through more efficient patient flow and timely access to information. Other activities included STD-based family planning services for patients (both women and men) who typically did not access personal health care providers. With minimal additional infrastructure costs, over the past 4 years, using Title X funding, the clinic expanded types of data collected and added breadth to service delivery. Annually, more than 5,000 individuals receive interventions to promote adequate family planning control.

System Use and Scope

After careful initial end-user workflow documentation, key functional objectives for the new system included elimination of virtually all paper forms (i.e., 25 logs, 2 encounter forms, multiple disease reporting forms, laboratory order forms, tracking systems, and multiple paper-based, quality assurance analytic tools). Over several decades, these developed to

support activities in a busy sexually transmitted diseases (STD) clinic. The user-interface needed to support an evolving set of data entry requirements coupled with automated data storage. The system needed to accommodate a modifiable data structure while linking to integrated advanced decision support. Features were designed to increase access, facilitate analysis, and enable communication with patients and other public health partners.

Given prior DPH experience, flexible data collection was required. Having used optical mark recognition (OMR) charting forms for nearly 2 decades, program leaders and clinicians needed a method to add new services and logic to support the process of population-based or public health care. Prevention messages included efforts to protect individuals from vaccine-preventable disease (e.g., hepatitis), reduced disease transmission (e.g., HIV), promote linkage to care (e.g., HIV), and avoid unintended pregnancies (e.g., family planning services for both men and women). With limited initial system scope, DPH focused on service delivery and decision support. Building capacity to increase the scope of data collected, allowed DPH to build a clinical delivery system which supports expanding program objectives and broadens capacity to deliver population-based care expected of a local public health department.

The user interface, developed with a visual tool, builds code to address changing data needs, new services, and decision support integration. The interface was designed to be a pen-tablet device that would permit end-users to carry the “chart” wherever clinicians were used to taking the paper forms in the past. Initial data storage was XML-based with nightly posting to a SQL database. Data are stored to promote reusability. Data destined for sharing are coded to standard vocabularies – diagnoses (ICD-9) and laboratory tests (LOINC). Information shared with DH and state health department laboratories need to use standard HL7 messaging services. Data (e.g., reportable infections, and laboratory test orders/results) are prepared and stored for secure File Transfer Protocol (sFTP) in batch mode, early each morning. Laboratory orders also need to interface to the clinical laboratory information system (i.e., Sunquest) using HL7 messaging.
The purpose of these technology investments was to improve business process efficiency, comprehensiveness and quality of care, while simultaneously supporting and promoting access to information by various public health (e.g., communicable disease surveillance and control, family planning) programs. Without an up front focus on the interfacing required of the HealthDoc system, the public health benefits would have been seriously curtailed – turning EHR data into actionable information (for the patient, clinician, laboratorian and public health practitioners) was a key functional requirement and priority.

Additional sponsorship for this new technology was provided by partnering with eHealth Services (eHS) group within DH. Skills to support a web-based data management system were beyond DPH Informatics Group capacity. This highly integrated project for DPH and eHS meant development and maintenance of HealthDoc would leverage existing eHS skills and services in data management, orchestration, and decision support. Decision support was written in HL7-based Arden Syntax; based on an informal review, this system continues to be the only non-vendor interface to this vendor’s (Siemens) rules engine. Without the rules engine, trust regarding data integrity would be limited. To effectively reuse data, the rules engine ensures high quality. For instance, to diagnose trichomoniasis, a laboratory test (i.e., wet prep) needed to be ordered and result posted consistent with that diagnosis. A man could not have a diagnosis of pregnancy, cervicitis and/or pelvic inflammatory disease. Rules additionally enhance the likelihood of following protocols that support both

personal and population prevention services (e.g., an injecting drug user, man who has sex with other men, person with chronic hepatitis C infection or sex worker all are eligible for hepatitis A vaccine). By passing data real-time to the rules engine during the visit, the process of care can broaden the capacity to deliver full scope essential public health services. Using Siemens within eHS, DPH reused established knowledge, technologies and resources; acquiring those skills and technology alone would force DPH into a steep new learning curve. By leveraging existing DH expertise, these decisions significantly mitigated risks and enhanced the likelihood of a timely project success, through repackaging readily accessible knowledge and skills.

Integration Level

Prior to full-scale paper to web-based EHR conversion, all users needed training. Training varied based on computer skill sets and created a challenge for users unfamiliar or unwilling to learn basic computer literacy and graphical user interfaces. Some long-term employees took this as an opportunity to leave the agency, requiring new clinician and laboratorian recruitment. Initial plans were to deploy with a pen-tablet device but clinicians complained about battery life, lost sessions and unfavorable form factor. Initial cycle time and patient flow were adversely impacted. Within 6 months, clinicians reverted to using desktop computers. Before enhancing interface functionality, primary data collection and end-user functionality needed to be addressed and stabilized. While the goal was to eliminate all paper forms, the absence of full integration and interfacing from day one meant some paper processes needed to continue. This created some consternation to employees and managers ready for elimination of all paper processes.

Among the functional objectives, capacity for loosely-coupled integration of data users with collected data was essential. Across the continuum of care - from patient to population, all data users (from clinician to policy makers) were interested in major automated interfaces to share information with the Colorado Department of Public Health and Environment (CDPHE) where disease reporting and laboratory services support the STD clinic and disease control program. HL7 messaging services utilize ICD-9 and LOINC encoded messages, respectively. XML-based data are delivered to CDPHE for ancillary data (e.g., risk factors for HIV) required for processing laboratory requests. Nightly, results from CDPHE to DPH are delivered automatically and uploaded into the electronic record.

Prior to development of this system, laboratorians specifically hired for the STD clinic conducted and completed their laboratory work entirely on paper forms; this work was separate and independent from work conducted by the DH main hospital laboratory. With HealthDoc, there was an effort to consolidate the supervision and quality control efforts of the STD clinic laboratorians into the main DH laboratory. That laboratory uses Sunquest information system, and with STD clinic laboratory consolidation, laboratorians needed one integrated interface into Sunquest. Orders placed by STD clinicians using the EMR encounter forms, automatically interface with Sunquest as a laboratory order. Laboratorian workflow is supported within the Sunquest environment, familiar to them for processing, sending, receiving and posting results to/from other facilities. All of these happen in the background, without any human intervention. No paper forms are completed.

As newer technologies became available, additional interfaces developed, including the provision of test results to patients over the telephone and on the Internet. Previously,

patients would call up and request results of clinical tests performed during a visit several days earlier. Results were typically stored in log books organized by test. Some results were then transcribed into one summary log book to make it easier for clinicians or clerical staff to retrieve information when a patient would phone for results, a laborious task that was difficult to maintain and potentially prone to errors. If results were not yet transcribed or one of many tests not contained on the summary log, the clinician or receptionist would retrieve one of many different log books to get the right information to answer the caller's needs. Now, the telephone call user interface is more comprehensive. Rapidly accessed, users find information, document a call, and monitor the time required to provide the results. Even more technology has been implemented since the go-live for clinical documentation. Results delivery now leverages the information system to store a patient's cell phone number and sends a text message to remind a patient of need to return to the clinic (for positive test result). Even further, results are now posted on-line with individual passwords issued at the point of care. All these services leverage information systems established to support clinical care. The benefit of these technology-mediated results delivery methods is that individuals and populations can reduce risk by short cutting time to delivery of disease treatment, containing further disease spread, thereby reducing ongoing population risk.

Privacy Protection

As DPH and DH-eHS began this integration process, the HIPAA privacy and security rules were just being implemented. DPH data are regulated under separate public health regulations, thus a hybrid (covered and non-covered) entity status was required for DH. While abiding by HIPAA regulations, DPH needed to protect public health clinic-derived information. Traditionally, efforts to segregate paper public health and personal health records have created barriers and inefficiencies. With the administrative controls available through active directory processes, DPH segregated information access based on user role and privileges. All individuals are authenticated with strong passwords when logging into the system. Only public health employees authorized to use this system have access to these records. Deployment of an organization-wide active directory is the technical mechanism by which individuals are granted permissions to specific data stores and applications. All DH employees are entered into this directory, roles are established, and authentication policies control the user initiation/enrollment, strength of passwords, and timing of change. All logins, accessed environments, and data movement are monitored across the agency with extensive network auditing enforced through technologies.

What previously required physical barriers (locked cabinets and facilities) now is accomplished by user accounts. The physical servers are all collocated in the secure data center for the entire agency. Underlying all health information exchange is a transport layer that supports either sFTP and/or https-mediated exchange. Data passed to the Siemens rules engine are de-identified before sending to the engine and then re-identified on return to the public health environment. The data that populate the public health records continue to be segregated from the larger DH environment as required by regulations.

System Implementation

Implementation of the electronic medical record was a one step process with a one-day conversion from the old scanned forms to the web-based tool. Staff training began several months in advance of go-live and continued after that. Over the ensuing months and years,

new staff typically had a much shorter learning curve than previously employed staff, and all current staff is completely comfortable with the system. Analysts needed to adapt to the SQL-based storage system and how to retrieve data to build standard reports used for program management, surveillance and disease control efforts. Training sessions in SQL queries and data structure were important as the structure was sufficiently flexible to accommodate new data required for care or population measures. Some processes (e.g., interfacing with the laboratories) were staged for change in later phases, thus some training needed to be delayed. Initially only about 25% of laboratory data were interfaced, this progressed to 60% and now approaches 100% direct interfacing of results.

The new web-based system allowed increasing access from off-site locations. After full deployment, STD clinic services and data collection were extended to the City and County of Denver - Jail Clinic (staffed by STD clinicians) with minimal effort. New sites (bath houses, detention centers and schools) are gradually being phased into the system. During initial implementation and for 18 months following, improvement efforts were primarily reactive to pressing needs or inefficiencies. Since then, a quality improvement cycle has been implemented that gathers ideas for new requirements (e.g., sites for deployment, additional service needs/offerings, data elements for research or program monitoring and new or modifications to existing interfaces). Ideas are assembled for review, prioritized and then resources identified to address enhancements or modifications to HealthDoc.

Implementation of bi-directional electronic messaging and reporting was performed in three phases. Phase 1 implemented morbidity reporting, phase 2 implemented HIV test reporting, and phase 3 implemented CDPHE laboratory test result reporting.

Phase 1, morbidity reporting, leveraged data already captured in HealthDoc. Morbidity reporting from the STD clinic to CDPHE was the first automated electronic messaging from HealthDoc, and for CDPHE. Data required for reportable disease messaging consisted of patient demographics, test results, and treatment information. Programs were written to extract these data elements for positive tests, mark records for transmission, configure the data in a standardized format, and securely transmit to CDPHE. With CDPHE information technology staff, discussions determined an acceptable format, processes developed, tests conducted, and data transmission and receipt initiated. Begun in October 2005, the system has been in production since July 2006. The phase provided valuable lessons and resulted in immediate process improvements for both DPH and CDPHE agencies.

Phase 2, electronic reporting of HIV Program Evaluation Monitoring System (PEMS) data (demographic, risk and prior test history), was developed to reduce paper form burden on clinicians and data entry at CDPHE. For each STD Clinic HIV test performed data must be submitted to CDPHE, as a requirement for funding. Although captured electronically for all STD Clinic patients, some information was not electronically available for all HIV Counseling, Testing, and Referral Services (CTRS) patients. To address this, a new abbreviated electronic form was implemented in HealthDoc. Until CDPHE finalized form revision, HealthDoc implementation efforts were delayed. Using lessons learned from electronic morbidity reporting, programs were developed to format and securely transmit data to CDPHE Parallel reporting, both paper and electronic, were conducted for about three months until electronic transmission proved as good, if not better, than paper-based data. Development began in November 2006 and is in production since October 2007.

Phase 3, laboratory test results delivery, electronically reported information from CDPHE to HealthDoc. As the first opportunity to accept electronic data from CDPHE by DPH, this Public Health Information Network (PHIN) compliant system accepts HL7 formatted test results. This phase required the most programming effort to ensure proper formatting and record matching between CDPHE and DPH data systems. Similar to previous phases, system validation required parallel processing and then final implementation. Development began in July 2007 and is in production since February 2008.

A current effort (**Phase 4**) is focused on improving the interface and laboratory results reporting from Sunquest, the DH laboratory information system and HealthDoc.

Current State

Currently, the system is fully deployed for all clinicians (N=20), physicians (N=12), laboratorians (N=4), policy makers (N=6), analysts (6) and patients (N~15,000/year) to document and/or retrieve all informaiton – this is the only mechanism for all STD, HIV, Jail Clinic, outreach (bath, schools) clinics to enter data for daily protocol-based STD and HIV prevention care. Data flow to the XML database and are posted nightly into a SQL structure. In collaboration with CDPHE, lab orders, diagnosis reporting, required ancillary data, monitoring of program services, and where appropriate, de-identified data are prepared and sent automatically to CDPHE. Data are readily available for DPH and CDPHE analysts to support reporting for policy makers. In collaboration with DH-eHS, DPH is working to create a data warehouse that uses business intelligence tools for end-user on-line analytic processing. Data are used by program managers and epidemiologists to monitor trends in sexually transmitted diseases, pockets of infection, and stratified analysis for identifying increased disease rates among specific demographic groups. Monthly reports are review by management, surveillance/epidemiology staff, and funders.

Enhancements beyond relatively rudimentary data quality check capacities in the prior OMR forms were required. With data entry, HealthDoc routinely checks data completeness, data inconsistencies (e.g., men who were pregnant), protocol concordance (e.g., for a specific diagnosis were proper test results recoded), and range validations (e.g., could an event occur in the future, or before an expected age). To inform clinicians about important public health measures or interventions, decision support results must appear at the point of care. Information can change the way care is delivered, allowing clinicians to follow protocols without having to remember each of the steps. Informing clinicians creates knowledge – for example, reminders during a clinical encounter encourage the provider to offer services (e.g., immunization and/or family planning), complete measures for interventions (e.g., document education), or recruit a patient for a research effort. The rules engine and conditional logic built into the forms are critical decision support success factors, affecting care delivered, quality of data collected, and population measures derived from the system.

Value of the Initiative

1. Success in Meeting Objectives

Value is gauged by specific progress toward the initial objectives. The DPH mission is to "promote, improve and protect the population's health through disease prevention and health promotion activities, direct clinical care, and other health services". The objectives

and measures that follow are for quality, process efficiency, productivity, completeness, and timeliness in the context of the DPH mission.

Reduce clerical activities and manual data exchange processes:

- Reduced general costs eliminating paper-based, filling, copying, seeking misplaced file and posting results
- CDPHE no longer has to print out 22,500 individual paper test result forms annually and transport them to the STD Clinic.
- Clerical staff no longer needs to input more than 22,500 test results annually into multiple test-specific logs. By automating the interface between laboratories and the HealthDoc systems, clerical work savings were equivalent to 832 hours annually.
- STD Clinic staff no longer fill out more than 2,500 morbidity reporting cards each year (625 hours/year)
- STD clinicians no longer fill out more than 11,000 HIV Program Evaluation Monitoring System (PEMS) forms each year, saving the equivalent of 365 clinician hours annually. Additionally, the notification time for PEMS forms reporting to State was reduced from an average of 2 days to less than one day.
- Improved data accuracy at the STD Clinic and State Health due to the elimination of potential clerical errors – even a 1% rate would mean 100-1000 errors/year
- Replacing a paper-based, scanned data entry system with a cost-effective web-based system that integrate clinical decision support

Increase clinician access to evidence-based protocols at the point of care:

- CDPHE lab test results are available in HealthDoc 2 days earlier than the previous paper-based processing system allowing more timely feedback to patients, reducing phone calls and searching for log books (estimate 2000 hours/year)
- End-users are guided to provide more comprehensive services
- HealthDoc facilitated services broadly support other program areas (e.g., vaccine preventable diseases, family planning, disease control, and surveillance systems) and essential public health service goals.

Support the rapid exchange of valuable surveillance data:

- DPH now has automatic, "real time", transfer of data to CDPHE on reportable sexually transmitted infections improving efficiency and reducing errors. The notification time for morbidity reporting to State Health was reduced from an average of 4.2 days to less than one day.
- Data from this system have supported the STD Surveillance Network (SSuN), a CDC-funded project that includes 18 STD sentinel surveillance sites across the country. Automatically-generated data from the STD clinic currently support three SSUN projects: enhanced gonorrhea surveillance, genital warts surveillance, and surveillance of trichomonas antimicrobial susceptibility. DPH is the lead on a first paper about this public health network (publication accepted to *Public Health Reports*)
- Recently initiated electronic transfer of all Title X (family planning) information to State Health on a monthly basis, with State Health commenting that no other agency has ever provided the level of accuracy noted with the first month of data transfer.
- Clinical systems support surveillance activities through Internet-based, health information exchange with extensive interoperability based on efficiently interfacing public and personal health information systems.

Support research efforts:

- The system supports the delivery of on-line laboratory test results to patients – enhancing patients' access to results as well as clinic efficiency by decreasing repeat phone calls (estimate: 25% of results delivered on-line).
- HealthDoc has been used as the primary database for a number of clinic-based research projects, including published evaluations of express visits and evaluation of opt-out, rapid testing, and provision of family planning services. Papers on online results and text messaging are underway.
- Recent recipient of a 3–year Office of Population Affairs grant award to evaluate the effectiveness and cost-benefit of providing integrated family planning and STD prevention services.

Apply decision support:

- Decision support permitted the clinic to generate automatic text messaging to alert persons to check results (when positive for gonorrhea or chlamydia) or to be re-screened

Reuse data for essential public health functions:

- Beyond individual patient care, effective diagnosis and treatment of infected persons generates secondary public health benefits by reducing ongoing spread of communicable disease, a cornerstone of public health and the rationale for publicly-funded STD clinics.
- Information immediately flows to each program improving the timeliness, completeness, and efficiency of surveillance systems or systems that monitor service delivery at a population level.
- Data are flexibly incorporated in quality improvement measures; new data or information may be added as needed through a modern, flexible, web-based system for authorized data access.
- The integration of services for the continuum of high risk behavior, education, early identification and diagnosis, treatment, contact investigation and linkage to care have been the hallmarks of "one stop" shopping for our clients facilitated by this system.
- Increased opportunities for collaboration and funding by local Denver Metro counties have been created by our efficiencies in this new system – 7 counties depend on DPH and pay for STD services; they receive timely county-specific usage reports.

2. Costs and Benefits Offsetting Costs

Resources for this effort were generated from grant funds supporting informatics work activities of the Denver Center for Public Health Preparedness and public health preparedness. Preparedness infrastructure investments were used to broadly improve the interoperability capacities of the public health department. Through active and automatic secure interfaces, authorized partners can rapidly share information during an emergency or disaster. Limited, national-level, ROI estimates[3] suggest a positive return and value for daily standardized health information exchange with public health. No formal HealthDoc ROI was completed; methodologically, this is nearly impossible given unreliable measures for extremely rare events (e.g., emergency or disaster) requiring public health response. The benefit of HealthDoc development is a lasting and functional secure transport mechanism to support information exchange beyond the scope of the sexually transmitted disease clinic (e.g., electronic laboratory reporting, rapid response and monitoring of communicable disease). DH, as a large safety-net provider (125,000 under- and uninsured

Denver residents), plus many services to other county residents now has automated reporting of 60 communicable diseases (by LOINC code and ICD-9), reusing many of these same HealthDoc infrastructure investments. Reporting times are significantly reduced with daily file transfers.

Estimated costs for initial implementation were on the order of $ 500,000 but did not include much in-kind support from multiple stakeholders. There have been significant and ongoing personnel savings through business process improvements (as described in the ***Value*** section). These efficiencies have permitted expansion of services to be more comprehensive for the population served by this clinic. Annual development investments have typically been about $50,000-75,000. No specific additional personnel have been hired but multiple analysts access the data supported by a variety of research-related programs; these same individuals serve as resources for more general data use. Total personnel funding to maintain, retrieve and analyze data is limited to about 1.5 FTE. However, there are many technology services provided in-kind by or through departmental service level agreements with DH.

In place for 3 years, modifications have made it possible to track and promote protocol-driven, service delivery for STD and other services (e.g., immunization and family planning) to more than 20,000 patients annually. Going from paper to electronic data entry has enhanced capacities to collect information for service and research activities. New research funding (Office of Population Affairs [OPA] and CDC) has been acquired based on HealthDoc pilot data and demonstration of system capacities. Major OPA-funded family planning themes include studies of: 1) benefits to clients and staff, 2) provider acceptance, 3) reduced costs, 4) effectiveness of reminders, 5) no unintended consequence of increased STD among family planning clients and 6) reduced unintended pregnancies.

The CDC-funded STD Surveillance System (SSuN) uses HealthDoc data as part of a multi-site study (over 40,000 STD clinic patients, 15,000/18 mo from Denver) to evaluate the effectiveness of a clinic waiting room video to prevent new STDs: the *Safe in the City* trial. The intervention significantly reduced new STDs by almost 10%. Data abstraction and transfer would have been all but impossible without the use of the HealthDoc system. [4] This now is a CDC evidence-based recommendation for Diffusion of Effective Behavioral Interventions[5].

Services provided in this clinic are for Denver's jurisdiction as well as the other 7 counties in the Denver Metro region. Some health departments desire regular reporting and files. The system prepares those files for transfer in a safe manner. Specifically for HIV-infected individuals, the services within the DH system are enhanced through the capacity to integrate and follow patients along the continuum of care: diagnosis, surveillance, linkage to care, treatment and education, adherence to treatment, and maintenance of prevention behaviors. Integrated directly into surveillance and monitoring systems, the data support the "closed-loop" of Process of Care – HIV (as shown in the earlier figure) to avoid missed opportunities to prevent disease spread.

Users are essential in informing how to enhance and improve the systems. Currently, clinicians have few real issues with the system. Issue logs are maintained and items tracked for inclusion in updates and phased enhancements. Informaticians constantly solicit *ad hoc* advice and ideas from the end users; situations arise where staff suggests a

new function, but typically, research funding drive new functionalities. These are logged, compiled and periodically reviewed to establish priorities and identify resources for development and implementation.

DH has been heavily influenced by the 'lean' process improvement efforts. With strategic partners (CDPHE and DH-eHS), DPH routinely (monthly) meets to define ways to improve processes and service. These are fundamental quality improvement efforts that seek to increase the data usability, promote greater automation, and monitor authorized access. Most of the changes introduced over the past 3 years have been through full team involvement to address clinical, service, programmatic and administrative needs. These have not been limited to individual level perspectives but typically are driven by processes that originate with clinically collected data that are processed and repurposed for population-based needs. Evaluations are fact-based, systematic, educational, and often point to innovations as solutions. Process improvement is part of the DH culture and how DPH manages and leads HealthDoc is reflective of typical organizational efforts.

3. Lessons Learned/Critical Success Factors

a. To what do you attribute your success?

- Strong buy-in to the concepts underlying the development of the new system serving both individual patient and public health purposes
- Old system was obsolete, enhancing motivation for the new system
- Collaboration with our partners
- Listening carefully to the users of this computerized system to ensure usefulness of the applications
- Willingness to experiment with new technology
- Available resources
- Finding technology solutions to solve issues of privacy and confidentiality concerns (e.g., anonymized rules engine identifiers for HL7 Arden Syntax messages was an entirely new approach for this global healthcare organization)

b. In hindsight, what do you wish you had known before you started?

- How to control risk and limit vendor costs by better project management
- Greater emphasis on functional requirements that anticipate and support transferability to other settings

c. Many other public health entities hope to implement electronic systems and need as much advice as they can gather. Share your thoughts on what is important:

In organizing the effort, in purchasing a system, etc.

- Being better organized and skilled at requirements definition gathering and business analysis. This would reduce consultant and vendor costs since these are less technically challenging development areas; simply understanding and documenting business processes with hand off to technical personnel would have saved significant resources.

In achieving the necessary technical performance.

- Partner with a strong technically skilled group. Having DH-eHS was essential in controlling our costs of deployment, maintenance and enhancements.

4. Dissemination

- NACCHO Model practice award 2006 and 2008

- PHIN presentations 2004, 2007

5. Transportability

From several informal reviews, HealthDoc (as it has been implemented) appears to have limited capacity for reproducibility. A concerted effort would be required to create more modular (and potentially more open-source) components. The standards (sFTP, service oriented architecture, XML, HL7, LOINC and ICD-9) are all embedded but the interfaces are built to partner's needs and processes. To share the software, encapsulation may be possible but a full-scale business requirements document should be developed for exportability to other environments. Part of the value of this system is that it leveraged what was available – Siemens rules engine, a specific transport security layer with CDPHE and the technical resources within DH. Unless those conditions were identical in other environments, DPH would need to standardize the interfaces and develop standard specifications for deployment elsewhere.

References

1. National Association of County and City Health Officials. *Operational Definition of a functional local health department*: http://www.naccho.org/topics/infrastructure/accreditation/OpDef.cfm; 2005

2. Davidson A, Cheatham M. Health Information Exchange Enhances Quality Improvement in Public Health. *NACCHO Exchange.* 2007;6:1-5.

3. Walker J, Pan E, Johnston D, Adier-Milstein J, Bates DW, Middleton B. The Value Of Health Care Information Exchange And Interoperability *Health Aff (Millwood).* 2005;w5:10-18.

4. Warner L, Klausner JD, Rietmeijer CA, et al. Effect of a brief video intervention on incident infection among patients attending sexually transmitted disease clinics. *PLoS Med.* Jun 24 2008;5(6):e135.

5. Centers for Disease Control and Prevention. Safe In the City. http://www.cdc.gov/STD/safe-in-the-city/default.htm.