Report on the Value of Health Information Technology at the Intersection of Clinical Practice and Public Health

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Contents

Introduction

"The question is no longer whether information technology will be used in health care…The discussion should now focus on whether HIT will support the models of care delivery that will help achieve broader policy goals: safer, more effective, and more efficient care"

Bitton et al 2012, 2593

Convergence of Clinical Practice and Public Health

Historically, public health has focused on health promotion and disease prevention efforts in large populations to achieve the greatest good for the most people. In contrast, clinical care has focused on the health of individuals. This division is reflected in the initial implementation and use of Health Information Technology (HIT) tools. These disciplines have relied on different sources of data to meet their separate goals.

However, the past decade has seen a convergence of goals in public health and clinical care. This is due to the rising costs of health

care in the United States (US) and recognition of the huge impact of preventable chronic diseases, such as diabetes and cardiovascular disease (CVD). As more patient information is regularly and reliably tracked through Electronic Health Records (EHR) and related technologies, it has become increasingly possible for public health practitioners and clinical teams to create targeted, efficient, and effective feedback cycles for health improvement.

EHR data are used in clinical practices for the treatment of individuals and to drive quality improvement (QI) to better serve patients. As medical providers are increasingly incentivized based on patient outcomes, new efforts have

arisen to identify cohorts of patients at risk for chronic disease, to target prevention and health promotion efforts at those most in need, and to better manage and monitor chronic diseases. There is growing appeal for electronic clinical data to "serve as a bridge" between public health and clinical care, to implement integrated population health surveillance, build accurate disease registries, identify high risk cohorts, and automate chronic disease management efforts. The growth of population health management (PHM) as a focus of clinical practice demonstrates the growing intersection and collaboration between the disciplines of public health and medicine.

The Centers for Disease Control and Prevention (CDC) has recognized and promoted this convergence through investments in programs such as California Department of Public Health's (CDPH) CDC-funded Lifetime of Wellness: Communities in Action and Prevention First: Advancing Synergy for Health programs. As a participant in these two programs, CDPH funds ten local health departments in the design and implementation of chronic care prevention and management strategies with partnering health care provider organizations, such as

community health centers. This report aims to provide program participants and stakeholders an understanding of the current evidence base for the value of HIT investments in the context of emerging opportunities for collaborative chronic disease prevention and management.

Methods

In preparation for this report, the study team conducted an extensive review of literature available on the value of HIT for clinical practice and public health efforts, focusing primarily on the prevention and management of hypertension (HTN) and diabetes. This literature review focused on articles published after 2009, when federal efforts initiated significant changes in the HIT environment. However, the technology landscape continues to evolve rapidly and some emerging trends may not be reflected in the literature. After an initial review of abstracts, 48 articles assigned the highest priority were reviewed and incorporated into this report. A complete listing of reviewed articles is included in Appendix A.

Health Policy and Technology Landscape

In order to understand current integrated efforts targeting some of the most difficult and pervasive health issues of our time, it is important to review how federal and state policies facilitate the development of electronic patient records and the expansion of health information sharing and analysis. These policies help shape industry trends to accelerate HIT implementation and its potential impacts on public health and clinical practice.

Value-Based Care

Triggered by the burden of high health care costs in the US with relatively low quality of outcomes,

two inter-related concepts—The Triple Aim and value-based care—have come to define health care policy in the past decade. These concepts are critical to the incorporation of HIT into both clinical practice and public health. The Triple Aim, first promulgated by the Institute for Healthcare Improvement (IHI) in 2008, implores stakeholders across the US health care system to improve the value of American health care through pursuing the goals of "improving the individual experience of care; improving the health of populations; and reducing the per capita costs of care for populations" (Berwick et al 2008, 760). The Triple Aim framework has spread widely and

become a fixture of health care strategy in the US (Whittington et al 2015).

Recent years have seen a significant shift in national funding for health care from a fee-for-service (FFS) model toward one of value-based care, which ties health care payments to outcomes. Under the FFS model, "financial success for providers does not equate with health-related success for the patient" (Badash et al 2017, 3), whereas value-based care incentivizes providers and the health care system at-large to generate greater efficiencies in the provision of health care services while maintaining or increasing the quality of care provided to patients. This approach is transforming practice in areas like chronic disease management to change the focus of clinical providers to more active prevention and management.

Chronic Disease Prevention and Management

Chronic diseases in the US today drive significant health care utilization and cost and have immense potential for intervention. Prevention, reduction of risk behaviors, and effective chronic disease management could drastically impact disease progression, quality of life, disability, mortality, and the costs associated with lost productivity and treating advanced disease. In 2012, about 50 percent of all adults had one or more chronic health condition, and 25 percent of all adults had two or more chronic health conditions. These patients account for a huge proportion of national health care spending, with 86 percent of the nation's $2.7 trillion annual health care expenditures going to treat people with chronic and mental health conditions. The CDC estimates that the total annual cost of CVD averaged $316.1 billion in 2012-2013, and the total estimated cost of diagnosed diabetes in 2012 was $245 billion including $176 billion in direct medical costs and $69 billion in decreased productivity. Heart disease, stroke, diabetes, and kidney failure are four of the top ten causes of death in the US. [1]

Additionally, the US continues to face health inequities among vulnerable populations. More people of color and low-income patients face the debilitating effects of chronic conditions, which in turn drive health disparities in the US (Baig et al, 2010). For example, it is estimated that in 2011-2014 African Americans, Asians, and Hispanics were almost twice as likely as whites to have diabetes (17.7 percent, 16.0 percent or 16.4 percent vs. 9.3 percent). Minorities were also twice as likely to have undiagnosed and unmanaged diabetes as whites (Centers for Disease Control and Prevention, 2017). In the US population that relies on Medicare for health insurance, the "management of chronic diseases consumes over 90 percent of Medicare expenditures and amounts to over $1.5 trillion per year" (Chen et al 2016, 1).

Research indicates that a reduction of a few key risk behaviors, early detection of people at risk for disease, and effective management of specific health indicators would have a significant impact on individual disability and systemic disease burden (Go et al, 2013). The majority of studies on HIT interventions for chronic disease prevention and management use HTN and diabetes as test cases because measured indicators are easy to track. For both diabetes and hypertension, there are straightforward data elements that can be used to identify patients at risk of developing the disease and who would benefit from prevention initiatives or identify undiagnosed patients who would benefit from screening. There are also clear indicators that track how well the patient and care team are managing the disease and improving health (e.g. A1C levels and blood pressure).

In spite of these promising circumstances, identifying and tracking at-risk patients using manually populated registries at the practice level has proven to be extremely time consuming, imperfect, and difficult. Therefore, chronic disease management in the past has often been reactive, relying on patients to seek care and to take the initiative for long-term follow-up. The adoption of more sophisticated disease management tools in EHRs and allied HIT systems over the past decade has begun to change the equation. As this report argues, the literature shows that proactive chronic disease prevention and management strategies are now broadly feasible.

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1. https://www.cdc.gov/chronicdisease/overview/index.htm

In this context of a maturing HIT landscape, diabetes and HTN illustrate the opportunity for increased collaboration between public health and clinical care. Numerous prevention and treatment measures for both diseases rely on health promotion efforts and individual behavior change. This has led to the development of a chronic care model that aligns community efforts and health system efforts (Figure 1).

Improvements in chronic disease management go to the heart of the Triple Aim and value-based care to enable clinicians to facilitate better outcomes for patients while lowering the staggering costs of the current health care system. Public health fits into the Chronic Care Model because patients with chronic diseases often require health promotion and disease

prevention programs (traditionally public health) as well as ongoing disease management and monitoring (traditionally clinical). In response, agencies are forming new collaborations and partnerships, facilitated by HIT, to transform their traditional roles.

Aligned Care Programs— Current Applications of Value Based Care Models

The Center for Medicare and Medicaid Services (CMS) and state entities like the California Department of Health Care Services (DHCS) have begun implementation of multiple programs to shift funding streams to value-based care,

FIGURE 1: THE CHRONIC CARE MODEL [2]
Developed by The MacColl Institute ® ACP-ASIM Journals and Books

The Chronic Care Model

Community
Resources and Policies

Health Systems
Organization of Health Care

Self-Management Support

Delivery System Design

Decision Support

Clinical Information Systems

Informed, Activated Patient

Productive Interactions

Prepared, Proactive Practice Team

Improved Outcomes
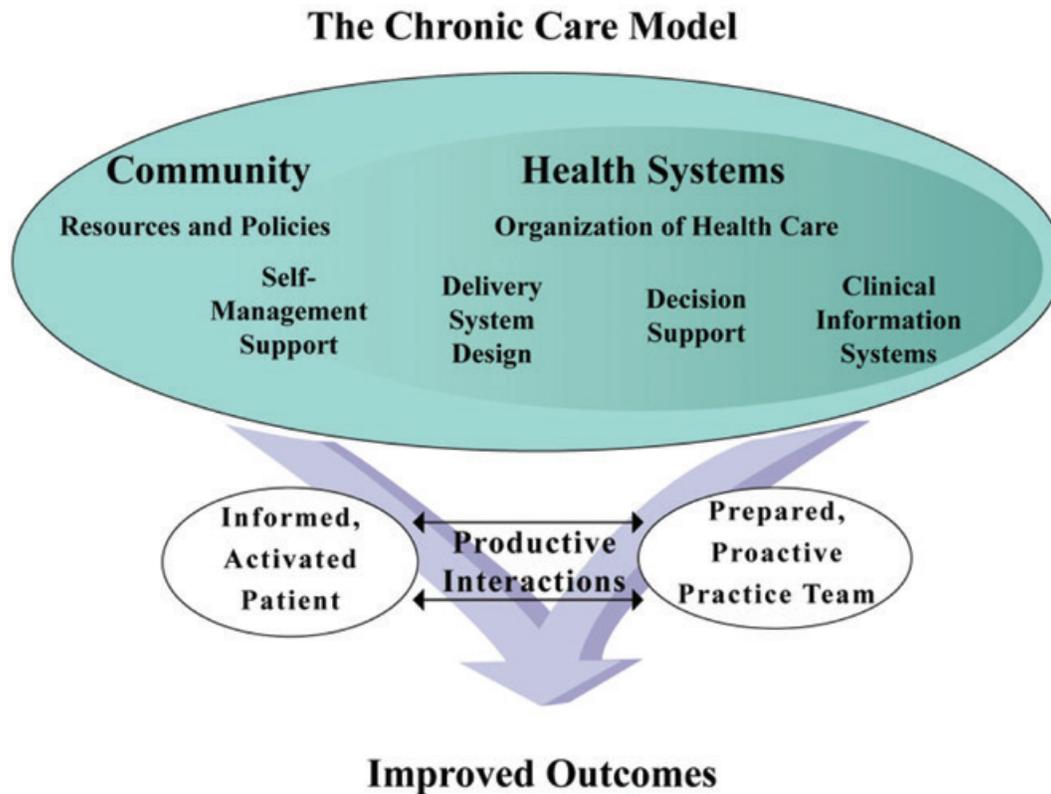
2. http://www.improvingchroniccare.org/index.php?p=the_chronic_caremodel&s=2

and all of these programs rely on a robust implementation of HIT tools. Programs such as DHCS' Health Homes for Patients with Complex Needs (HHP) and Whole Person Care (WPC) require care coordination and the sharing of care plans, necessitating the careful implementation of care planning technology to potentially suit a wide variety of organizations. Other CMS endeavors include wholesale changes to reimbursement practices, as performed through the shift to the Merit-Based Incentive Payment System (MIPS) and Alternative Payment Models (APMs).

MIPS and APMs incentivize Medicare providers to seek efficiencies in the provision of quality care, which can be achieved in part through careful implementation and use of HIT. Beginning with 2017, MIPS will evaluate provider performance and calculate positive or negative payment adjustments on four performance categories: Quality, Advancing Care Information (ACI), Resource Use, and Engagement in Clinical Practice Improvement Activities (CPIA). By establishing incentives based on an overall ranking of providers against their peers, the program additionally incentivizes providers to aim for the highest scores possible. While HIT is a practical necessity for achieving high MIPS scores, the direct implementation and use of HIT tools for specific purposes also generates points for MIPS categories in their own right. A variety of activities involving HIT can be undertaken to satisfy the requirements of the CPIA category. These include: participation in a Patient-Centered Medical Home (PCMH); implementing EHR enhancements for the capture of behavioral health data; engagement of patients through implementing improvements to a patient portal; using a certified EHR to capture patient-reported outcomes; leveraging a Qualified Clinical Data Registry (QCDR) for a variety of activities; and the provision of telehealth services to expand practice access.[3]

Under a provision of the Affordable Care Act, DHCS has begun implementation of the HHP program, which aims to improve data sharing and care coordination for vulnerable populations with chronic diseases. The HHP program requires sharing of data between physical health care, behavioral health care, and social/community-based services with a single coordinator known as the Community Based Care Management Entity (CB-CME), with administration of the program and delegation of risk falling to the Medi-Cal Managed Care Plans. As the program is further developed and implemented, HIT will play a key role in the administration of the program, as the effective management of these complex target populations by CB-CMEs require extensive integration of care activities and a robust HIT infrastructure to share data and care plans between many types of providers.

A similar program aiming to provide the impetus for improved care coordination for vulnerable, complex, and high-utilizing populations is the WPC pilot program. Beginning with a first round of pilot programs in 2016 and with a second round of pilots awarded in 2017, the DHCS Medi-Cal waiver program targets improvements for severely vulnerable patients through the patient-centered coordination of health, behavioral health, and social services. Unlike the HHP program, local government at the county and city level manage these pilot programs in collaboration with Medi-Cal managed care plans, community partners, and other local entities. This five-year program leverages up to $1.5 billion in federal funding for the development of the technical and organizational infrastructure necessary to collaborate in the provision of care for high-risk, high-utilizing Medi-Cal beneficiaries.

Each of these programs offer examples for how federal funding can be immediately leveraged to impact care and cost, while building structures that can aid in the provision of care beyond the timeline and target population of the initial program itself. With the proper care and attention in developing the infrastructure required for HHP, WPC, and similar programs, providers and the community at large have the opportunity to build up the supports necessary to better serve their populations without the potential risks and costs associated with implementing new technologies or refining care delivery systems on their own.

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3. https://qpp.cms.gov/mips/improvement-activities

Health Information Technology Development

This new orientation toward value-based care mandates an unprecedented level of information sharing and use. Therefore, one of the key strategies for achieving the Triple Aim has been expanding HIT tools to empower clinicians, track patients, and evaluate outcomes.

The last decade has seen tremendous growth in the adoption of HIT, both in the implementation of EHRs as well as through participation in Health Information Exchange (HIE) activities and organizations. Much of this growth is attributed to the passage in 2009 of the Health Information Technology for Economic and Clinical Health

(HITECH) Act, which invested over $30 billion in incentives for hospitals and health care providers to adopt HIT systems. Under HITECH, the Meaningful Use (MU) EHR Incentive Program provides financial incentives for eligible physicians and hospitals to adopt and use EHRs in their practice. The Medicaid version of the MU program provides incentives of $21,250 per provider in the first year for adoption, implementation, or use of Certified Electronic Health Record Technology (CEHRT) and incentive payments of $8,500 for up to five years, ending in 2021, for meeting targeted goals on ten measures of utilization of EHR technology (Figure 2).

EHRs have become increasingly commonplace in the HITECH era. While only about 9 percent of

FIGURE 2: MEDICAID EHR INCENTIVE PROGRAM OBJECTIVES AND MEASURES

Eligible Professional Objectives and Measures	Hospital Objectives and Measures
Protect Electronic Protected Health Information through appropriate technical capabilities	**Protect Electronic Protected Health Information** through appropriate technical capabilities
Use **Clinical Decision Support (CDS)** to improve performance on high-priority health conditions	Use **Clinical Decision Support (CDS)** to improve performance on high-priority health conditions
Use **Computerized Provider Order Entry (CPOE)** for medication, laboratory, and radiology orders	Use **Computerized Provider Order Entry (CPOE)** for medication, laboratory, and radiology orders
Generate and transmit permissible discharge prescriptions electronically **(e-Prescribing)**	Generate and transmit permissible discharge prescriptions electronically **(e-Prescribing)**
Provide a **summary care record** for transitions of care or referrals	Provide a **summary care record** for transitions of care or referrals
Identify **patient-specific education** resources for patients, using relevant information from EHR	Identify **patient-specific education** resources for patients, using relevant information from EHR
Perform **medication reconciliation** when seeing patients from another care setting or provider	Perform **medication reconcilization** when seeing patients from another care setting or provider
Provide **patients with electronic access** to their health information	Provide **patients with electronic access** to their health information
Use **secure electronic messaging** to communicate with patients on relevant health information	
Perform **Public Health Reporting** of electronic public health data from EHR	Perform **Public Health Reporting** of electronic public health data from EHR

FIGURE 3: OFFICE-BASED PHYSICIAN ELECTRONIC HEALTH RECORD ADOPTION[4]
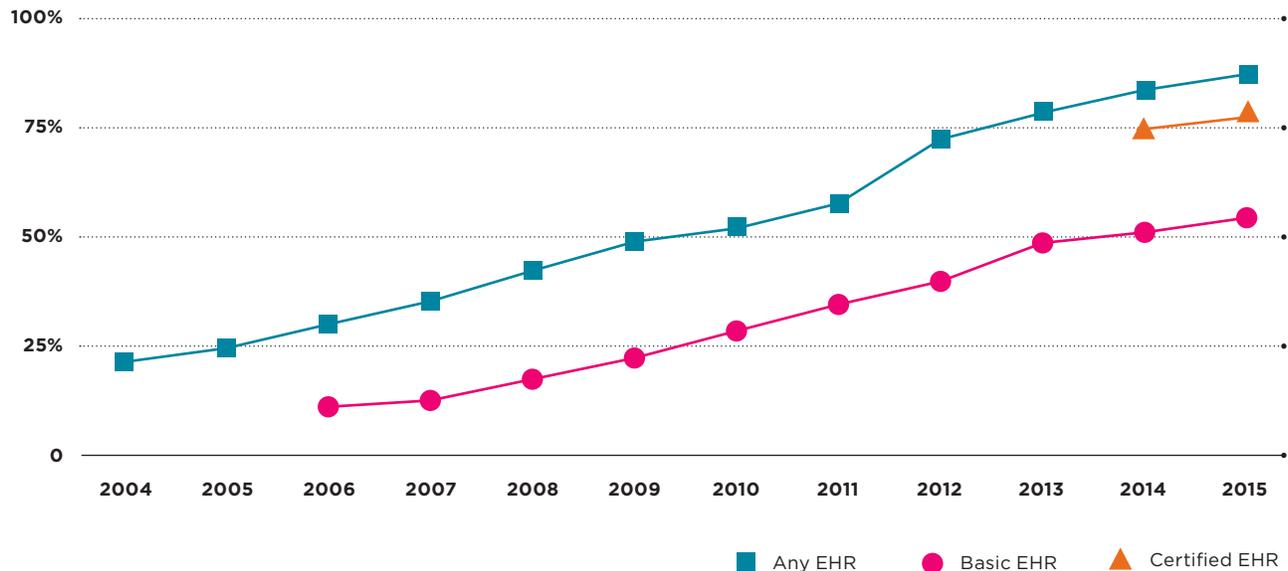
hospitals in 2008 had implemented an EHR with basic functionality, 72 percent possessed Certified EHR Technology by 2011 and over 96 percent had done so by 2015. The implementation of the MU incentive program is estimated to have driven gains in hospital EHR adoption of eight percent annually in the first five years of the program (Adler-Milstein and Jha 2017, 1422). EHR adoption is also prevalent among physicians outside of the hospital environment, as shown in Figure 3.

Now that EHRs have become commonplace, the current frontier is in implementing data analytics tools that maximize the use of EHRs and the adoption of HIE. Developments in both of these areas are advancing the move toward PHM as a strategy for improving health care delivery and outcomes. An important ongoing activity impacting the adoption and effectiveness of HIT has been the establishment of standards for health care systems and data. One example is standards for system interoperability or, "the ability of health information systems to work together within and across organizational boundaries in order to advance the effective

delivery of healthcare for individuals and communities."[5] Federal efforts to establish standards for interoperability began in 2005, and public and private efforts continue to establish frameworks for the exchange of data between actors in the health care landscape (Bernstein 2013, 6–7). As HIE efforts coalesce around standards, stable models for governance are established, and sustainable funding of Health Information Exchange Organizations (HIOs) becomes more widespread, barriers to adoption of HIE have diminished.

Health Information Technology and Public Health

EHRs and HIE are transforming public health practice, opening up new data sources for disease surveillance and prevention efforts. The data supplements traditional sources of information and are giving new flexibility to public health practitioners to understand local communities and design community-level interventions.

4. https://dashboard.healthit.gov/quickstats/pages/physician-ehr-adoption-trends.php
5. http://www.himss.org/library/interoperability-standards/what-is-interoperability

Led by CDC in the US, public health agencies implement national and state systems to monitor the health of the nation (Croft 2013). Surveillance data are gathered through large, population-based surveys that track a set of health indicators to create a longitudinal picture of health in different populations or track progress on different diseases or health issues. For example, the National Health and Nutrition Examination Survey (NHANES) has been tracking chronic disease in the US since 1959. The current format, developed in 1999 and conducted every other year, includes both health interviews and clinical examinations of a national, representative sample and tracks chronic disease, infectious disease, and environmental exposure. Historically, surveillance focused on infectious disease and disease outbreaks to monitor, target response, and track progress toward goals. More recently, surveillance activities have "expanded to include other conditions including injuries, birth defects, chronic medical conditions, mental illness, illicit drug use, health behaviors and environmental exposure." (Paul et al 2015, 210). These data sources allow public health officials, clinicians, and researchers to track disease, set priorities, and develop interventions. However, they have limitations in timeliness and relevance to public health officials' understanding of local communities or populations.

As EHR use has spread to a more representative sample of hospitals and practices, many researchers are investigating EHR data as an additional tool for agile and up-to-date disease surveillance. Perlman et al compared using EHR data for surveillance to two well-established reference surveys: the New York City (NYC) Health and Nutrition Examination Survey and the NYC Community Health Survey. Their study showed that EHR data for diabetes, HTN, smoking, and obesity prevalence indicators performed well, but depression and influenza vaccination estimates were substantially lower than survey estimates (Perlman et al 2017, 855). As EHR data coverage becomes more complete and standardized, they hypothesize it becoming an important complement to public health surveys, especially to focus-in on smaller geographical areas or patient populations.

Health Information Technology and Chronic Disease Management

The emphasis on value-based care is bringing public health promotion efforts into clinical practice, especially for chronic disease management. Clinicians are asked to identify patients at-risk of adverse health events and then proactively tailor care so that it is relevant to their needs.

Bauer summarizes many key tenets of value-based care programs in his discussion of collaborative care for chronic disease management and emphasizes the role for HIT. He states, "The delivery of effective collaborative care is based on five key principles: care is patient-centered, evidence-based, measurement-based, population-based, and accountable (University of Washington AIMS Center, 2014). Effective HIT is vital to the delivery of collaborative care" (Bauer et al 2014, 168). Bauer maps the principles of collaborative care to clinical processes and the required corresponding HIT capabilities in Figure 4.

Due to the synergies between HIT capabilities and clinical processes, and, we would add, public health goals, health care policy and practice increasingly includes HIT as a core component of both clinical care and public health endeavors

Principle	Clinical processes or tasks	Health IT capabilities
Patient-centered care	Patient education Patient engagement and activation Self-management support Shared decision-making to negotiate a care plan Effective coordination and collaboration among providers and patients	Education and self-management tools are delivered in multimedia format through the internet, mobile web, and mobile health apps and are accessible to patients at any time and from any location. Patient medical records are accessible through patient portals. Communication between patients and providers is facilitated through secure email. Care plan and key patient outcomes relevant to the care plan are visible and can be shared effectively across providers and with patients.
Evidence-based care	Shared decision-making to negotiate a care plan Accessible evidence-based behavioral interventions	Educational materials for patients and providers emphasize effective treatments. EHRs or registries include clinical decision support and treatment algorithms for providers. Technology-enabled delivery of evidence-based psychosocial interventions (by telephone, internet, mobile devices, or in computer-assisted formats) increase dissemination of evidence-based care.
Measurement-based care, Treat-to-Target	Adjustment of care plan until clinical target achieved Systematic outcome monitoring	Registry contains relevant data that may be entered by providers or by patients on clinical status and barriers. Data may be from standardized instruments for symptom self-report, vitals, labs, or passively collected sensor data. Registry triggers alerts to providers for patients who are not improving.
Population-based care	Systematic outcome monitoring Proactive outreach	Registry tracks all patients initiating care—not only patients who present or return for services—and contains data on visits and outreach efforts, highlighting patients who are not engaged in care, and triggering alerts to providers for patients who are not improving. Registry is available to care managers and consultants. Telemedicine assessments and remote delivery of behavioral interventions can extend services to difficult-to-reach populations.
Accountable care	Quality improvement	Registry aggregates data on processes and outcomes at the provider, practice, or organizational level.

Findings on the Value of Health Information Technology

The ability to collect, analyze, and share data quickly, efficiently and safely is a key component of the Triple Aim framework for health care. When fully implemented, HIT has the potential to impact all three goals: improving patient care and experience, improving the health of populations, and reducing the per capita costs of health care. Since health systems are still in process of implementing effective EHRs, expanding those EHRs with analytic tools, and connecting systems through HIE, the evidence for impact is still varied and preliminary.

The discussion in this section outlines the evidence on the value of HIT for chronic disease prevention and management and is organized by how tools are currently applied: to improve public health practice, to improve clinical practice, or to "act as a bridge" between the two. In each of these sections, we highlight a published case study that best illustrates the value of HIT. In addition to the effects on processes and outcomes, we also discuss evidence found for cost reductions. Summaries of all reviews and articles are included in Appendix A.

Health Information Technology and Public Health

HIT has clear benefits for public health practice through increasing data sources for surveillance and providing new strategies for designing and targeting interventions. In the US, data aggregation and sharing solutions are developing at the local or regional level, in response to local resources and needs. Both HIT applications are reviewed below and illustrated using a case study example.

Data Analytics for Surveillance and Monitoring

The MU program requires that providers use their EHR to submit electronic surveillance reports to public health agencies, incentivizing collaboration and participation in monitoring population health. One recent international review of efforts to use EHR data to support public health saw promise in building national data sharing infrastructure, but few countries had successfully implemented national systems. Instead, successes tended to be more focused or local. The authors summarized, "data extracted from integrated EHR networks offer the potential for rapid ascertainment of the health status of populations in care, for targeting interventions to vulnerable populations, and for monitoring the impact of such initiatives over time. Challenges remain, including issues of sampling, data quality, interoperability, and privacy" (Paul et al 2015, 214). Local surveillance solutions have developed through a variety of data sharing partnership structures: health department led efforts (e.g. the New York MacroScope or Colorado's Health Observational Regional Data service-see case study below), academic institution partnerships (like Chicago's Health Atlas or Harvard's MDPHNet) or developing HIEs (like the WNY Beacon Community led by HEALTHeLINK) (Perlman et al 2017, 853).

In addition to using EHR data for near-real-time clinical information, researchers are using EHR data to get a better idea of health characteristics in smaller geographies to target community-based interventions. One of the strategies for patient-centered care involves designing local, tailored interventions. Gabert et al investigated a population-based approach using EHR data to target diabetes and HTN interventions toward high-risk neighborhoods with the greatest need. They explained, "Most studies rely on data sources representing large geographic regions, such as hospital referral regions, counties, states or the entire country… [A]ggregated EHRs offer a novel approach for identifying the small, high risk neighborhoods that are missed by the larger regions identified in health examination surveys. Our results suggest that regularly-collected EHR data may be a useful, low-cost approach for identifying the hotspots where diabetes prevention programs can have the largest impact" (Gabert et al 2016, 7).

Surveillance Case Study; New York City Macroscope: The New York City (NYC) Department of Health and Mental Hygiene's (DOHMH) Macroscope illuminates multiple facets of HIT value. They describe their approach as "a population health surveillance system that uses electronic health records (EHRs) to track conditions managed by primary care practices that are important to public health."[7]

The DOHMH's Primary Care Information Project has been supporting EHR adoption for primary care practices to increase delivery of preventive services, reduce chronic disease risk factors, and improve disease management. A subset of over 700 practices that all use the same EHR (eClinicalWorks) has agreed to share aggregate data with the DOHMH. These practices serve over 1.5 million patients. The NYC DOHMH defined disease indicators that were important to public health surveillance, including prevalence of diabetes, hyperlipidemia, HTN, smoking, obesity, depression, and influenza vaccination, as well as treatment and control of diagnosed diabetes, hyperlipidemia, and HTN. (Perlman et al 2017, 854). They compared the indicators to established public health surveys and concluded, "Validation findings from the NYC Macroscope and early results from similar emerging systems suggest that prevalence of diabetes, smoking, HTN and obesity are good indicators for EHR-based surveillance in jurisdictions with functioning EHR networks" (Perlman et al 2014, 856).

These aggregate clinical data allow the NYC DOHMH to support public health practice in a variety of ways that bridge public health and clinical care and allow them to be current and more community-focused. They:

- Internally assess population health, develop policy, and more finely target programs

- Regularly report back to providers highlighting opportunities for preventive services with their patients

- Allow providers to compare their data to similar practices in the city

- Respond within 24 hours to requests for information from providers or researchers

NYC Macroscope researchers are finding, "EHR-based surveillance systems can be cost effective and timely, and can provide prevalence estimates for local communities and smaller subpopulations. Especially when used in conjunction with other data sources, they can provide a comprehensive and accurate picture of the health of a defined population" (Perlman et al 2017, 856).

Public Health Interventions [6]

Many examples of EHR and HIE integration illustrate how public health departments are using new sources of data and new clinical- community partnerships to develop and implement public health interventions. Surveillance tools that provide refined information about health needs help localities design and implement community-level interventions.

Public Health Intervention Case Study:

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Minnesota is considered one of the "heart healthiest" states in the US, but it also has immense disparity in diabetes and CVD biomarkers and risk factors. Researchers can use EHR data to identify disparities hidden in aggregate statewide measures and to target interventions to the county and zip code level. Gabert et al describe using EHR data, centrally aggregated by a nonprofit called Minnesota Community Measurement, to identify diabetes and HTN "hot spots" in two urban counties and one rural county. They identified "7 heavily burdened zip code areas burdened by a disproportionately low level of control for cardio-metabolic risk factors" (Gabert et al 2016, 6). The HealthRise Project then brought together the Minnesota Department of Health, county and city health departments, local Accountable Care Organizations (ACO), other health care providers, and non-governmental organizations to plan community-based interventions for these areas. Three community-based organizations were awarded grants for demonstration projects in 2015 to creatively address detection, management, and control of CVD and diabetes in those counties and zip codes.[7]

In addition to surveillance and targeted intervention, other public health initiatives are increasingly conducted through collaboration with clinical partners. This convergence is particularly seen in the areas of PHM, tracking and analyzing social determinants of health (SDOH), and patient engagement for chronic disease prevention and management. Those examples are discussed after the next section on clinical practice.

Health Information Technology and Clinical Practice

Value-based care and the demands for population health management (PHM) to control debilitating and costly chronic disease are creating new demands on clinical practice. HIT tools have the potential to assist with this transformation. There are many HIT approaches designed to improve the processes of health care that impact patient care and experience. These tools can be used by or targeted to providers, patients, or the health system. Examples of each are provided in Figure 5.

In addition to improving processes of care and creating coordinated care teams, practitioners anticipate these tools will improve patient outcomes and population health. There have been many studies of HIT tools to review their effects, but broad conclusions about the effectiveness of given tools or treatments can be unclear due to variances in implementation, functionality, scope, or other limitations. See Appendix B for a listing of reviewed articles and a summation of the direction of their findings. We discuss the evidence from these articles in the sections below.

With the accelerated adoption of EHRs and HIT, researchers are investigating whether they improve care quality, especially related to diabetes and other chronic disease care. Before 2011, the literature did not show clear benefits of EHR implementation over paper-based practices since the systems were in different stages of implementation. Ahmad and Tsang assessed

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6.   https://www1.nyc.gov/site/doh/data/health-tools/nycmacroscope.page

7.   http://www.health.state.mn.us/divs/healthimprovement/working-together/partnerships/healthrise.html;
https://www.health-rise.org/healthrise-us/

FIGURE 5: HIT TOOLS FOR CLINICAL CARE (ORGANIZATIONAL FRAMEWORK ADAPTED FROM BAIG ET AL 2010, CONTENT DEVELOPED BY THE AUTHORS)

Provider Focused Tools	Patient Focused Tools	System Focused Tools
Clinical Decision Support (CDS) including treatment algorithms	Web-based patient education to support disease self-management	Educational materials are evidence based
Providers have access to EHRs	Patient portals for access to medical records and information	
Secure email for patient-provider communication	Secure email for patient-provider communication	
Online care plans are visible to clinical team	Care plan is visible to patient and provider	Patient records are visible across care teams via HIE
Registry data on processes and outcomes are regularly shared with care team for quality improvement (QI)	Patients participate in disease self-management and tracking through mobile health devices and apps	Registries track diseases or populations of interest, informing QI at practice and organizational levels
Registry triggers alerts to providers for patients who are not meeting care goals or not receiving care	Patients receive automated reminders for screenings, appointments and required follow-up	Program and care managers receive targeted alerts via HIE when patients in specific cohorts have specified touches with system (e.g. Emergency Department visits)

that, "A limitation to these studies–a potential explanation for the equivocal results–is that they aggregate practices using EHRs without differentiating between those with and without high-functioning EHR systems. The functionalities and usability of different EHR systems vary substantially, and these abilities may affect the ability of EHRs to influence care quality" (Ahmad and Tsang 2013, S358). However, recent studies are finding that EHR practices are more able to meet screening and disease management goals than paper-based practices. For example, Smith reviewed recent studies conducted at Federally Qualified Health Centers (FQHCs) and summarized that, "Increased health information technology capacity in FQHCs was associated with improved quality of care and that safety-net practices with EHRs demonstrate higher levels of diabetes care and better outcomes compared with FQHCs that use paper based systems" (Smith et al 2016, 1).

One finding routinely demonstrated in the literature is the critical importance of the "human element" in HIT implementation, wherein strong leadership and staff buy-in are highly important factors for success (Buntin et al 2011, 470). Care and planning in the selection and implementation of HIT is another critical element, as solutions are not typically "one-size-fits-all," but highly customizable tools that need to be carefully integrated into workflows and practice in order to achieve success. As demonstrated in a controlled study of primary care physicians in New York, these benefits are most likely to be realized when providers engage with "high levels of technical assistance" (Jones et al 2014, 50) to guide them through the process from assessing organizational needs to selecting the right vendor and implementing technology in a controlled manner. Any organization or practice implementing HIT is encouraged to make use of expert assistance and guidance to maximize

potential for improved organizational and patient outcomes.

Generally, studies suggest that in order to be impactful, HIT must be implemented in the context of careful QI initiatives that involve key stakeholders, have adequate institutional support, and are adapted to be relevant to local practices and patient populations (Watts 2016, Shelley et al, 2011). IT tools must also use target measures and CDS tools that are evidence-based and proven to be effective.

Studies also show that that it takes time to see the benefits of HIT implementation. Practices that are further along in HIT adoption have better process and patient outcomes. As practices adopt EHRs and providers become comfortable with using them, EHRs can support practice improvement and patient care initiatives. For example, early phases of EHR implementation see more progress in process outcomes than patient outcomes (Benkert et al 2014). On the other hand, practices and clinicians with experience using certified EHRs are more able to meet electronic clinical quality measures (eCQM) for chronic disease outcomes like controlled blood pressure (Heisey-Grove et al 2017). In addition, EHR platforms lay the foundation for later tools that can assist clinical decision-making, engage patients and facilitate communication.

Coordinated Care

One challenge faced by providers with paper-based practices is sharing information with and about complex patients; particularly those who are served by many types of providers and who access care in a variety of locations. Managing such patients can result in both high costs and poor patient outcomes. Given that such complex patients "typically visit multiple providers, improved care coordination is one important means of improving the effectiveness of their care. Despite this need, the care of complex patients is generally poorly coordinated" (Rudin et al 2016, e317). Patients with chronic disease requiring long-term management also benefit from coordinated and personalized care (Chen et al 2016).

Researchers see a great deal of potential in HIT to support care coordination: "The move toward service models that provide effective chronic disease care represents a major paradigm shift

in medicine that is in its early stages. HIT tools can naturally extend the chronic care paradigm and enhance the resolution of effective models such as coordinated care to provide treatments that are truly adaptive and delivered in real time" (Bauer et al 2014, 5). HIT can better involve patients as a member of their care team. One reviewer wrote, "HIT provides an opportunity to organize disparate data sources into one cohesive, patient-centered record. It can enable the engagement of patients, improve the collaboration with and between caregivers and contribute to efficient and safe personalized care" (Steichen et al, 34). In particular, authors identify four opportunities for EHRs to work to coordinate care: 1) reconciling medications, 2) tracking lab tests, 3) communicating across settings, and 4) mediating care plans between disciplines (O'Malley et al 2010 cited in Bates 2015). Yet, barriers and concerns remain over the feasibility of implementing each of these types of coordinated care strategies because of the lack of standardization and systems interoperability (Bates 2015).

In addition to developing better tools for medications, labs, and sharing care plans and information, many care coordination barriers relate to staffing, workflow and HIT implementation. Challenges include creating well-defined roles, responsibilities, and protocols within and across organizations, and implementing adequate workflow and work culture changes and training when implementing coordination tools (Rudin et al 2016, e318). In practices that do not have the EHR capability to communicate with other systems "in order for such capabilities to bridge this EHR gap, care coordinators were often required to manually translate information (e.g., physician orders) from the EHRs into separate care plan software" (Rudin et al 2016, e320). Manually transferring these data can be time consuming, costly, prone to errors, and unsustainable (Kim et al 2017, 213). However, there remains little evidence in the literature that " use of IT tools for coordination will result in enough savings to justify purchasing and using the tools" (Rudin et al 2016, e318).

HIT tools can help care coordination by assisting in personalizing care or identifying patients with gaps in care. For example, using EHR data, algorithms can automate patient stratification for HTN, dividing patients into groups that require

different levels and types of care (Chen et al, 2016). Another group in New Zealand uses EHR data to strengthen its coordinated care program for HTN control by identifying gaps in medication adherence, which are then addressed by care team members through personalized counseling and follow-up (Warren et al 2012).

Clinical Decision Support

Clinical Decision Support (CDS) and Computerized Physician Order Entry (CPOE) are well-studied functionality for EHR technology (Jones et al 2014, 51). In the case of CDS and CPOE, numerous studies point to the positive benefits that such functionalities have on clinical practices and, as a result, have led to adoption by clinicians. An extensive review of the effects of the MU incentive program, found that "CDS generally results in improvements in the processes targeted by the decision support," and that neutral or negative results speak more to the "specifics of the particular intervention, context, or implementation" (Jones et al 2014, 52) than to the effectiveness of these functions as a whole.

Various studies have examined utilizing CDS tools for chronic disease management and assisting clinicians in meeting care recommendations. For example, "Optimal care for patients with diabetes involves following a number of care recommendations, such as blood pressure, cholesterol, and hemoglobin A1c control, annual eye and foot screenings, smoking-cessation counseling, and healthy-lifestyle education. The literature suggests that diabetes-specific decision support can lead to modest, though variable, improvements in care quality, and many of the studies vary substantially in quality of study design" (Ahmad et al 2013, S359).

CDS tools that include many strategies (both clinician focused and patient focused) have the biggest impact on follow-through and outcomes. One study described the implementation of a multi-faceted, automated, EMR-based CDS tool for diabetes management in the Providence Health System in Oregon. Implementation required very little clinician training, used an out-of-the box EMR solution, and showed significant impact on diabetes indicators. They concluded, "The results of this study suggest a synergistic effect when multiple physician-directed strategies are implemented within an HIT system augmenting an EMR" (Hunt et al 2009, 172). Another clinical trial looked at the impact of the CHICA CDS tool for identification of youth at-risk for type 2 diabetes (T2D). This CDS tool uses pre-screening data to identify patients at risk of T2D. It then facilitated screening and follow-up with both clinician-focused prompts and patient/parent focused education and reminders. The clinical trial demonstrated a significant increase in screening and participation in a scheduled follow-up appointment (Hannon et al, 332). Multi-faceted approaches that tie in clinician focused CDS tools with patient focused outreach, education, and communication tools appear to have the biggest impact.

Health Information Exchange

Introducing HIE functionality can assist practices in a number of areas (Khurshid et al 2012) as shown in Figure 6.

FIGURE 6: HIE USE CASES

Care Coordination	Chronic Disease Management
Efficiency	Effectiveness
Transitions of Care	Patient Safety
Population Health Management	Quality Improvement
Reducing Duplicative Testing	Reducing Readmissions
Simplifying Administrative Services	Timeliness of Data Sharing

HIE use within hospital emergency departments has also been shown to reduce inpatient admissions and length of stay (Tzeel et al 2012), or the need for duplicate lab and imaging tests, procedures, diagnostic tests and medication ordering (Janakiraman et al 2017, 22), improving patient experience and reducing costs. As with other aspects of HIT, a common finding is "…the benefits of using HIE increase with physicians' experience with the HIE" (Janakiraman et al 2017, 24). To receive the best value from working with a HIE, providers should educate their patients on HIE, take care in integrating HIE into workflows, and have champion HIE users (Eden et al 2016).

In addition to constructing a data-driven foundation for achieving the Triple Aim, HIT implementation and integration is building a bridge between public health prevention and disease control efforts and clinical chronic care management. Case studies discussed in the convergence section below highlight innovative approaches to creating real-time, responsive, proactive data repositories to support public health interventions, academic research, and clinical care for communities with a high disease burden. HIEs are one tool for facilitating increased integration of physical health care, mental health care, social services (homelessness, substance use treatment, etc.), and other providers to deliver better care to the highest utilizers of our health system.

Patient Safety

Many functions and outcomes associated with investing in HIT also provide improvements in patient safety, benefitting both patients and providers. Three-quarters of studies in one review demonstrated reductions in medication errors through use of HIT, particularly through CDS and CPOE (Jones et al 2014, 50). Medication reconciliation is one of the objectives in the MU program and a required function for Certified EHR Technology.[8] Accuracy in medication lists can also be improved through use of HIE to import medications prescribed at other connected locations. As discussed earlier, the use of HIE also demonstrates benefits for patient safety as shown by reduced inpatient utilization

and shorter lengths of stay (Jones et al 2014; Tzeel 2012). Implementing best practices, such as educating all health care staff in the use of HIT and implementing relevant alerts (Meyers and Shannon 2012), help to improve patient safety. The use of HIE also makes for "easier and timely access to patient information at the time of diagnosis [which] helps health care providers make correct diagnosis" (Janakiraman et al 2017, 8).

Quality Improvement

QI initiatives using electronic health data are where most providers begin with using the data to change their practices. QI spans all levels of implementation and all sectors of practice and EHRs, HIEs, and registries are clearly essential to providing real-time, actionable data. Baig summarized, "QI using HIT can improve adherence to guideline-based care, enhance surveillance and monitoring, decrease medication errors, and decrease utilization of care" (Baig et al 2010, 3).

Almost all studies that discussed the implementation of EHR tools at the practice level to improve chronic disease care for HTN (Benkert et al 2014; Heisey-Grove et al 2017; Shelley et al 2011), diabetes (Baig et al 2010) or both (Smith et al 2016) included active QI initiatives. These played an important role in engaging stakeholders in systems change as well as measuring progress and impact.

For example, Open Door Family Medical Centers, located in New York, used a QI process to assess the effectiveness of implementing a multicomponent HIT intervention including provider performance feedback and CDS to promote adherence to HTN clinical guidelines and improvements in BP control. They found, "a theory-driven approach to tailoring HIT to local context through user input and an iterative testing process can facilitate adoption of HIT. Moreover, when implemented as part of a multifaceted QI initiative, tailored to the local context, and developed with local user input, HIT can play a central role in assessing performance, improving adherence to care standards, and improving

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8. https://www.healthit.gov/sites/default/files/meaningfulusetablesseries2_110112.pdf

HTN-related patient outcomes" (Shelley et al 2011, SP109). Patients were 1.5 times more likely to have controlled blood pressure post-intervention than pre-intervention.

HIT tools can assist with QI initiatives regionally or across practices when data are shared through HIEs. The registry case examples on pages 20-21 demonstrate using robust QI processes in the development and implementation of registry tools (Watts et al 2016; Heider et al 2014). In addition, a primary motivation for implementing system wide-disease registries is to be able to implement performance improvement initiatives related to chronic disease care both within a large health system (Veterans Health Administration) and across a community by comparing performance within and between practices (Western NY).

Cost Reduction

In addition to assessing the value of HIT for improving clinical care and patient outcomes, many studies have quantified the return on investment of implementing technology; that is, the costs of implementation compared to cost savings generated by more efficient care or prevention of adverse health outcomes. Studies on the effect of HIT in generating cost savings are limited and many tools are still being evaluated, but the literature is encouraging. The largest body of knowledge in the literature studies the effectiveness of CDS and CPOE, while scientific studies covering the benefits of other EHR functions or HIE are represented less robustly in the literature (Jones et al 2014, 51). However, studies do commonly find a positive association with cost reductions through CDS, CPOE, HIE, and the generation of patient lists by condition (Jones et al 2014, 52).

One study team modeled different options for IT enabled diabetes management (registries, CDS, remote monitoring, patient self-management systems, and payer-based systems) to try to estimate the cost savings if the tools were fully implemented. They estimated significant savings, "Over 10 years, diabetes registries saved $14.5 billion, computerized decision support saved $10.7 billion, payer-centered technologies saved $7.10 billion, remote monitoring saved $326 million, self-management saved $285 million, and integrated provider-patient systems saved $16.9 billion." They also suggested that there might

be a synergistic effect of more integrated and complete implementation of IT enabled tools that could impact many related facets of chronic disease care and management:

> IT-enabled diabetes management has the potential to improve care processes, delay diabetes complications, and save health care dollars. Of existing systems, provider-centered technologies such as diabetes registries currently show the most potential for benefit. Fully integrated provider-patient systems would have even greater potential for benefit. These benefits must be weighed against the implementation costs (Bu et al 2007, 1140).

A variety of studies have demonstrated the effectiveness of HIE in providing financial returns in specific instances, with positive effects ranging among "shorter emergency department length of stay, reduced diagnostic turnaround times, shorter time to the initiation of appropriate therapies, and more in-person time with patients" (Jones et al 2014, 51). A retrospective analysis of hospital readmissions and HIE system usage in Rochester, NY from 2009 to 2010 found that HIE system access was associated with a 57 percent decrease in the likelihood of readmission and associated savings of "$605,472 annually, accounting for an estimated 48 potentially avoided readmissions each year" (Vest et al 2015, 437). The ability of the HIE literature to quantify cost savings at this point faces the limitation that "the studies published to date have been heterogeneous, varying in settings, patient populations, types of exchange partners, and technology platforms" (Vest et al 2015, 435-436).

Health Information Technology at the Intersection of Public Health and Clinical Practice

Population Health Management (PHM) and information sharing strategies like HIE, PHM clinical tools and analytics, patient engagement strategies, and identification of SDOH have grown out of the shift towards value-based care. They exemplify the current overlap between public health and clinical care, require HIT solutions, and are often used by innovative chronic disease prevention and management programs. Evidence

for the value of HIT for PHM through registries and similar technologies, patient engagement and the SDOH is discussed below.

Population Health Management / Registries

HIT tools are used to build registries for community efforts to identify patients at risk of chronic diseases, to diagnose patients with early disease (like pre-diabetes or HTN) and develop, implement, and share care plans for ongoing disease prevention and management. Therefore, in addition to surveillance that helps define policy and target public health interventions, HIT has the potential to greatly improve chronic care management by coordinating management efforts at many levels (regional, systemic, practice). The NYC Macroscope, described above, is an example of a regional disease registry that provides data to many different types of users and bridges disciplines.

Others are building proactive patient engagement into health systems with accessible functionality that improves clinical care workflows, identifies groups of patients by disease or other care needs, and then monitors progress over time. HIT with analytic capabilities can allow both retrospective assessments of clinical performance as well as proactive identification of patients and outreach for prevention or management. Adding analytic

capacity to EHR or registry tools can help providers analyze risk factors in order to stratify patients by disease type and then into sub-categories of disease that help determine care plans (Chen et al 2016, 9). In the past, practices have created their own simple spreadsheets to track groups of patients with similar intervention needs. However, Bauer argues, "…superior registries are centralized and cloud-based, supporting access by multiple users, including care managers and consultants. The registry should allow sorting and actively alert providers through prompts that identify patients who have not been following up or who are not improving, so that outreach efforts can focus on these patients" (Bauer et al 2014, 171). Two examples of registries that inform both public health surveillance as well as clinical PHM are described below.

Often, individual patient-focused EHRs must be adapted to include the analytic capacity to support PHM. The examples below describe two different challenges. The first describes adapting data within a standardized system to be relevant at the local level and responsive to specific disease management. The second describes the challenges of integrating data across disparate practices in a region in order to create a disease registry for PHM across unlinked practices and hospital systems.

Registry Case Study; Integrated Health System example:

Veteran Health Administration. The Veterans Affairs medical system has an advanced EHR that has been in use for over a decade. However, it is designed for individual patient care. The Veterans Health Administration developed a number of national population management tools to allow local staff to access population level information for diseases such as Hepatitis C and others. While these tools were helpful for disease surveillance, they were not agile enough for local PHM. The Cleveland Veterans Affairs Medical Center identified three limitations they wanted to address, "1) little local control over types of data

collected, 2) timeliness of the data, 3) ability to effectively monitor and intervene for QI"(Watts et al 2016, 233).

The Cleveland Veterans Affairs Medical Center engaged in an iterative QI approach to engage stakeholders to develop and implement disease specific PHM registry tools that worked for their local care teams. The process included steps to: 1) clarify team-based care needs, 2) develop and implement tools by a core team and relevant stakeholders, 3) disseminate across clinics and a broader group of users, and 4) use the tool for QI projects. They summarize three key lessons

Registry Case Study; Integrated Health System example *(Continued)*

learned: "1) Subject matter experts who can bridge the clinical and IT landscapes are essential team members, 2) It is essential to involve a variety of clinical stakeholders from the start, and 3) Flexibility to tailor the population management registry tools to specific clinical needs is critical" (Watts et al 2016, 237).

Starting with an advanced EHR within a coordinated system, the team found that the investment was modest and the benefits were tangible, "The development and implementation teams found that a team-based population management registry tool addressing multiple clinic-based needs could be developed and successfully integrated into existing care processes with relatively limited local resources. The tools empowered team members to engage in more efficient, coordinated team-based care, and enhanced QI efforts. Local PHM tools can organize information to facilitate outreach by nurses, pharmacists, and other clinical providers between visits and to optimize timing, frequency, and content of face-to-face clinical visits" (Watts et al 2016, 238).

Registry Case Study; Community Registry example:

Western NY Beacon Community. In contrast to the structured Veteran Health Affair system, Heider et al describes the lessons learned from linking 98 practices using over 20 different EHRs into a diabetes disease registry in Western NY (WNY). The Office of the National Coordinator for HIT selected WNY as one of 17 Beacon communities. HEALTHeLINK, the local regional Health Information Exchange Organization (HIO), was the lead agency for the WNY Beacon program. An overarching goal of the program was to improve diabetes care in primary care settings. The purpose of creating a community diabetes registry was to provide primary care practices with PHM capability and to drive QI by providing practices with feedback on their achievement of diabetes CQMs over time.

The project required careful coordination between the HIO, vendors, and primary care practices. HEALTHeLINK worked closely with the vendors, first developing a customized registry report with the dominant local EHR vendor. Once it was established, they developed solutions with the other five EHR vendors working with practices in the area. Two Clinical Transformation Partners (CTPs) were engaged to work with practices to implement and maximize usage of the registry for both PHM and benchmarking (Heider et al 2014, 3). Practices with valid data received quarterly benchmarking reports. They also worked with the CTPs to identify and target patients with uncontrolled diabetes for follow-up and additional interventions.

The study team identified the following technical and implementation lessons.

Technical Lessons

- Establish clear technical specifications for the registry.
- Invest effort in data mapping.
- Anticipate the need for data normalization.
- Develop clear protocols to support practice staff.
- Understand that practices and vendors are both overwhelmed and do not speak the same language.
- Anticipate that vendors have competing priorities.
- Learn how to work with vendors.

Implementation Lessons

- Learn how to work with practices.
- Address data sharing concerns up front.
- Use peer groups to provide legitimacy.
- Leverage existing relationships to gain momentum.
- Gain buy-in by showing value to practices.

Social Determinants of Health

A relatively new frontier in leveraging data through HIT is the SDOH, the "conditions in the environments within which people live, learn, work, play, worship, and age that affect a wide range of health, functioning, and quality-of-life outcomes and risks."[9] The public health literature has solidified the importance of these factors on individuals' health, and strides are being made to improve the capabilities of HIT solutions to collect and share SDOH data so that it may be meaningfully used in both the provision of clinical care and in the practice of public health. As the inclusion of SDOH data in practice is quite new, the extant literature in the domain of HIT cover pilot studies on the integration of SDOH data for the provision of care for patients with chronic diseases and recommendations for how SDOH may best be standardized for data sharing and analysis.

At the clinical level, the collection of SDOH data allows for a more individualized and tailored approach to treating patients. As more data is collected and studied and our understanding of the relationships between social factors and responses to various treatments increase, the analysis of SDOH data for a patient will allow providers to "create a distinct patient phenotype where therapy and interventions are tailored to the individuals unique circumstance" (Milani et al 2017, 376). One study of the Medicaid population in a PCMH in upstate New York incorporated SDOH data into the information shared in transitions of care. It showed that including SDOH data "transformed clinical practice and improved outcomes for patients (Hewner et al 2017, 1). While incorporating the data "was a significant challenge for the clinical practice, and it took months before the staff saw the value of systematically collecting this information… once tracking mechanisms were in place, and after experiencing a few success stories, the staff embraced the concept and took initiative to modify the interventions to improve outreach" (Hewner et al 2017, 10).

Patient Engagement

Patient engagement is an essential component of chronic disease prevention and management and exemplifies the public health/clinical care link. HIT has created a myriad of new opportunities for sharing information with patients, facilitating ongoing communication between visits, encouraging behavior change or self-management of disease, and tracking and sharing health indicators. These systems also have the potential to save time and reduce errors or missed opportunities through automated tasks.

Because many of these strategies have been implemented slowly or inconsistently, the evidence for their impact on patient outcomes, practice efficiencies, or cost savings is limited, but there are some promising results (Ahmad and Tsang 2013). Below we discuss examples of strategies used in clinical practice for chronic disease management and the evidence to support impact.

In general, findings suggest that patient engagement strategies incorporated in a larger care plan or supported by personalized interactions with a provider are more successful or have a larger impact than those used in isolation. One review of diabetes self-management strategies summarized components that seem to be generally effective, and that "the most effective interventions incorporated all the components of a technology-enabled self-management feedback loop that connected people with diabetes and their health care team using two-way communication, analyzed patient-generated health data, tailored education, and individualized feedback" (Greenwood et al 2017, 7). While automated, general information or patient-driven interventions could be useful, those that were personalized or integrated into coordinated care efforts were more impactful (Figure 7).

Researchers caution against allowing the digital divide to exacerbate health disparities. They recommend careful attention to content, modes,

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9. https://www.healthypeople.gov/2020/topics-objectives/topic/social-determinants-of-health
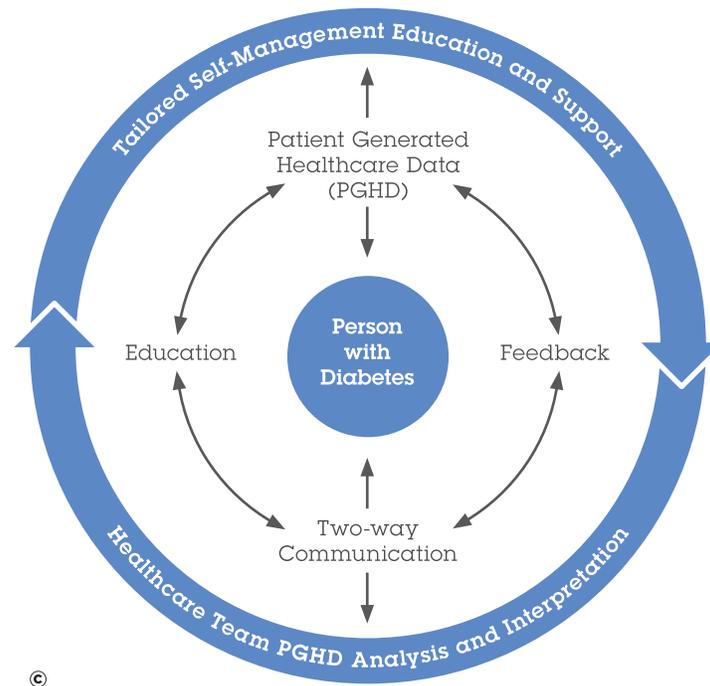
language, and marketing to ensure that strategies and materials reach a diverse audience and patients most in need of the information or tools (Coughlin et al 2017, 4; Bauer et al 2014, 168).

Additionally, practices must re-examine workflows and staffing when implementing patient engagement strategies. Some practices are concerned about implementing online patient engagement tools because they are worried about the impact on workload and workflows, ability to provide appropriate content, and the staffing needed to respond in a timely manner to patient inquiries (Coughlin et al 2017, 5; Bauer et al 2014, 171).

Outreach and Communication

Legislation over the past few decades has increased patient access to health records and information. After the Health Insurance Portability and Accountability Act (HIPAA) passed in 1996, patients were entitled to see, get copies of, and amend their health records, which resulted in development of the first patient portals.

MU criteria included specific EHR capabilities for patient communication and engagement: developing secure messaging for communication, the ability to access and download health records, the ability to send health education materials, automated patient reminders for preventive services, and medication reconciliation (Coughlin et al 2017, 2).

Recent reviews have examined the literature covering specific strategies for patient engagement and have found mixed evidence of impact. For example, one review of patient engagement tools from 2013 did not find clear evidence of their ability to impact patient diabetes outcomes. They indicated that, "examples of specific [patient engagement] strategies include: (1) filling out a questionnaire on diet and exercise prior to a visit, to be reviewed during the visit; (2) sending reminders to patients via secure email or text on healthy behaviors or upcoming, preventive visits; (3) uploading glycemic data from patient glucometers for regimen titration; and (4) enabling online

medication refill and scheduling. Data supporting the benefit of these HIT strategies are limited" (Ahmad and Tsang 2013, S359) due to the number of small, short studies included in the review sample which found small positive effects but did not study the effects of strategies for a sustained period.

Coughlin et. al. reviewed the impact of patient web portals for disease prevention and management. They found that portals tethered to EMRs have had varied results and the causal pathways for impacts are not always clear. A majority of the studies showed positive results for patients who engaged with tools offered by patient portals for chronic disease management. For most of the 12 articles described, direct communication with providers (either their clinician, a pharmacist or personalized care manager) resulted in significant improvements of diabetes or blood pressure indicators, while passive features did not have significant results. For example, one study in Tennessee found that use of secure messaging was associated with greater glycemic control, while just having access to lab results or the ability to review their medical record was not associated with glycemic control (Coughlin et al 2017).

Studies that examined the impact of preventive services portals had consistently positive impacts. In all four studies, patients who participated in portals that combined access to their EHR with personalized prevention information and reminders were more likely to be up to date on age and sex appropriate screening procedures (Coughlin et al 2017, 3).

Education and Self-Management

Stage 2 of MU requires that practices implement a secure messaging feature in their EHR. Therefore, this feature has been more consistently applied in practice than many other patient engagement strategies.

Recent evidence solidly supports use of technology for patient education and self-management of chronic diseases like diabetes. Greenwood et. al. conducted a meta-review of articles between 2013-2017 of technology for diabetes self-management education and support services. Of 25 studies, the majority were on mobile phones and secure messaging and 18 of 25

reviews reported significant reduction in A1c as an outcome measure (Greenwood et al 2017; Kuo et al 2016). Four key elements, described in Figure 7, emerged as essential for improved A1c; these elements include: (1) communication, (2) patient-generated health data, (3) education, and (4) feedback. They argue that the evidence supports a process of physicians and patients actively sharing and interpreting information and data to develop and maintain a personalized diabetes care plan. They concluded, "The evidence from this systematic review indicates that organizations, policy makers, and payers should consider integrating these solutions in the design of diabetes self-management education and support services for population health and value-based care models" (Greenwood et al 2017).

Coughlin reviewed studies of disease specific web-portals as another strategy for patient education and chronic disease self-management (Coughlin et al 2017, 3). Six of the 12 articles reviewed related to diabetes care and self-management. However, all of the portals were extremely different in design and purpose. Additionally, some stood alone while others were connected to a personalized care management intervention. Therefore, it was difficult to assess the impact of this type of patient engagement intervention.

Integrating Patient-Generated Data

With the rise of new technologies that individuals can use to collect their own health data—from pedometers to wearables to at-home blood-pressure and glucose monitors—there has been a collective push to include this new trove of patient-generated health data (PGHD) into health records for the benefit of providers. If standards are developed for the classification of such data and their transmission into EHRs, then these technologies may show benefits for practice and may provide richer data sets for public health surveillance. One very promising avenue for such collection is through home-based blood-pressure readings, which, "better predict cardiovascular risk than do office measurements, [and] are more reproducible" (Milani et al 2017, 377). This also opens an avenue to provide near real-time interventions to improve HTN control and keep patients with chronic diseases engaged with their providers. Researchers are testing ways to

use existing, off-the-shelf, low-cost products to integrate patient health data in order to facilitate adoption of these types of engagement and management tools (Marquard 2013).

Just as with educational materials and patient self-management strategies, patient generated health data is useful if it is easily integrated

and is used to monitor a care plan. According to Greenwood, "Simply tracking PGHD is not sufficient; data need to be analyzed for patterns and trends in relation to the individual participant and these data need to be interpreted and shared with the participant in a meaningful way to change the plan of care" (Greenwood et al 2017, 7).

Future Directions

The current literature covering HIT abounds with examples of pilot studies that point the way toward the future of health care and the treatment and prevention of chronic diseases. Numerous pilot studies are testing methodologies for the identification of patients with undiagnosed chronic conditions (Gabert et al 2016; Hannon et al 2017), including via Machine Learning (Chen et al 2015), as well as other pilots for outcomes-monitoring-dashboards, practices for patient messaging, and for telehealth (patient-provider) and eConsult (provider-provider). The history of HIT development and implementation to date provide lessons learned that will benefit future developments if followed. The continued growth in value of HIT will be well-serviced by the incorporation of patients, providers, and experts in the development of tools, and coalescing around national interoperability standards in the service of supplying patients and providers with access to data (Adler-Milstein et al, 2017).

Value-based care program implementations are highlighting the challenges and necessity of data sharing agreements and systems interoperability, particularly in wrap-around care initiatives that seek to integrate physical health, behavioral health, substance use disorder treatment, and social services information. Many are currently grappling with implementing secure methods of sharing sensitive data with diverse providers on a care team in order to improve care for complex and chronic patients, in ways that comply with federal laws.

The SDOH data will continue to be incorporated into health data collection, to the benefit of both

clinical practice and public health. As practices and vendors further integrate SDOH data, incorporating limited, standardized, and brief questions to be stored as discrete data will be important to facilitate the exchange of data and will be very useful for value-based care programs that necessitate the sharing of SDOH data (Adler and Stead 2015, 701).

In order to best realize the value of investments in HIT for clinical outcomes and/or cost reductions, provider organizations need to carefully design workflows and optimize processes when making changes to incorporate new technologies in to practice. In research and in implementations, there is a need for "understanding how to integrate EHRs seamlessly into clinical workflow and to better train and support providers during implementation" (Ahmad et al 2013, S358).

Appendices

Appendix A: Listing of Reviewed Articles

Appendix B: Summary of Article Findings

Appendix C: Acronyms Glossary

Appendix A:
Listing of Reviewed Articles

Author & Publication	Year Published	Article Title	Brief Description
Adler-Milstein, J, and Jha, A; Health Affairs	2017	HITECH act drove large gains in hospital EHR adoption	Study comparing hospital EHR adoption rates under HITECH Act with adoption rates at ineligible hospitals.
Adler-Milstein, J, et al; J Am Med Inform Assoc	2017	Crossing the health IT chasm: considerations and policy recommendations to overcome current challenges and enable value-based care	Policy considerations to improve the value of HIT and its support of Triple Aim in the future.
Adler, N, et al; New England J of Med	2015	Patients in context - EHR capture of social and behavioral determinants of health	Discussion of Institute of Medicine-proposed standard measures of social and behavioral determinants of health for EHR vendors to incorporate.
Ahmad, FS, et al; American Journal of Preventive Medicine	2013	Diabetes prevention, HIT and Meaningful Use: challenges and opportunities	Outlines HIT-based strategies for improving diabetes prevention.
Baig, AA, et al; Medical Care Research and Review	2010	Review Paper: The use of quality improvement and HIT to improve diabetes outcomes in African American and Hispanic patients	Review of HIT interventions in minority patient populations; includes patient-oriented, provider-oriented and systems oriented QI initiatives. Value of HIT for tracking and reducing health disparities.
Bauer, AM, et al; Preventive Medicine	2014	Aligning health information technologies with effective service delivery models to improve chronic disease care	How HIT and collaborative care models support and reinforce each other. Registries and CDS, patient education and self-management, patient-provider communication.
Benkert R, et al; Appl Clin Inform.	2014	Diabetes and HTN quality measurement in four safety-net sites: lessons learned after implementation of the same commercial electronic health record	Variation in implementation of the same EHR in four sites. Examined the use of EHR data for QI to improve diabetes and HTN care.

Author & Publication	Year Published	Article Title	Brief Description
Bu, D, et al; Diabetes Care	2007	Benefits of information technology-enabled diabetes management	Computer model to determine the financial and clinical benefits of implementing HIT-enabled diabetes management systems.
Buntin, M, et al; Health Affairs	2011	The benefits of HIT: a review of the recent literature shows predominantly positive results	Largely positive results found in review of literature, except for instances where there was a lack of buy-in or extenuating circumstances (turnover, vendor issues)
Cebul, RD, et al; NEJM	2011	EHRs and quality of diabetes care	Compared paper-based sites to EHR sites in a regional quality collaborative for achievement of diabetes care and outcomes targets.
Chen R, et al; IEEE Biomed Health Inform	2016	Patient stratification using EHRs from a chronic disease management program	Developed a fully-automated method for stratification of hypertensive patients for customized care programs.
Coughlin, SS, et al; Risk Manag Health Policy	2017	Patient web portals, disease management, and primary prevention	Review of patient portals for chronic disease prevention and management. Tied to EHR, disease based portals, or portals for increasing preventive care. Discussion of barriers.
Eden, K, et al; Intl J of Medical Informatics	2016	Barriers and facilitators to exchanging health information: a systematic review	HIE use facilitated by focus on policies and training, single sign-on, opt-out model, proxy users, and managed expectations. Barriers include completeness of information and organizational/workflow issues.
Gabert, R., et al; PLOS One	2016	Identifying high-risk neighborhoods using electronic medical records: a population-based approach for targeting diabetes prevention and treatment interventions	Examines whether home neighborhood has an effect on diabetes outcomes using EHR data. Other data sources don't focus that finely (city or county-wide) Used to target public health interventions.
Gottlieb, L, et al; Am J Prev Med	2015	Moving electronic medical records upstream: incorporating social determinants of health	Examines 3 case studies for integrating SDOH into EHRs, identifying functions that EHRs can perform to facilitate integration.
Green, B, et al; Am J Prev Med	2014	e-Care for heart wellness: a feasibility trial to decrease blood pressure and cardiovascular risk	Evaluating whether a web-based dietician-led team care intervention decreased BP, CVD risk and weight.

Author & Publication	Year Published	Article Title	Brief Description
Greenwood, DA, et al; J Diabetes Sci Technology	2017	A systematic review of reviews evaluating technology-enabled diabetes self-management education and support	Meta-analysis, focusing on texting and secure messaging for Diabetes self-management and education.
Hannon, TS, et al; JAMA Pediatr	2017	Effectiveness of computer automation for the diagnosis and management of childhood type 2 diabetes: A randomized clinical trial	Tested a computerized CDS in an EMR to identify pediatric patients at high risk for T2D and coordinate screening and diagnosis of prediabetes. Pre-screener form, provider worksheet, telephone reminders.
Heider, AR, et al; EGEMS (Wash DC)	2014	Developing a community wide EHR disease registry in primary care practices: lessons learned from the Western New York Beacon Community.	Developed a diabetes EHR disease registry across primary care practices in Western New York using diverse EHR systems.
Heisey-Grove, DM, et al; J Am Med Inform Assoc	2017	Electronic clinical quality measure reporting challenges: findings from the Medicare EHR Incentive Program's Controlling High Blood Pressure Measure	Examining practice factors associated with 1) accurate reporting of the clinical quality measure that calculates the proportion of patients with HTN who have controlled BP and 2) achieving >= 70% HTN control.
Hewner, S, et al; eGEMs	2017	Integrating social determinants of health into primary care clinical and informational workflow during care transitions	Case study demonstrating incorporation of SDOH into EHR and workflows, showing results of improved practice and patient outcomes.
Hunt, J, et al; Informatics in Primary Care	2009	The impact of a physician-directed HIT system on diabetes outcomes in primary care: A pre- and post-implementation study	Implemented CareManager, an automated EMR based CDS tool to determine impact on patient outcomes and ability to conduct disease registries or surveillance. Very little physician training and no additional staff support.
Janakiraman, R, et al; SSRN	2017	Study on the effects of health information exchange access on health care quality and efficiency: an empirical investigation	HIE use in emergency departments result in reductions in length of stay, 30-day readmit rate, and number of doctors participating in care. Demonstrated through patient-level data in NY State.
Jones, SS et al; Annals of Internal Medicine	2014	HIT: an updated systematic review with a focus on meaningful use	Review of studies on effectiveness of HIT functionality in MU regulations, finding strong evidence supporting CDS and CPOE. Calls for greater inclusion of implementation and context in studies.

Author & Publication	Year Published	Article Title	Brief Description
Karmali, KN, et al; Cochrane Database Syst Rev	2017	Risk scoring for the primary prevention of cardiovascular disease	Risk scoring for CVD prevention.
Khurshid, A, et al; Perspectives in Health Information Management	2012	HIE: metrics to address quality of care and return on investment	Development of common metrics to demonstrate value of HIE are key in assisting EHR adoption and investment.
Kim, JY, et al; Psychiatr Rehabil J	2017	Integrating health care for high-need Medicaid beneficiaries with serious mental health illness and chronic physical health conditions at managed care, provider and consumer levels	Integrating behavioral and physical, HealthChoices HealthConnections pilot program in 3 southeastern Pennsylvania counties.
Kuo, A., et al; Telemedicine and e-health	2016	Secure messaging in EHRs and its impact on diabetes clinical outcomes: a systematic review	Eleven articles reviewed for impact of secure messaging on diabetes outcomes. Evidence is limited but suggests improvements in primary outcomes.
Ma, J, et al; JAMA Intern Med	2013	Translating the Diabetes Prevention Program lifestyle intervention for weight loss into primary care	Evaluated two adapted DPP lifestyle interventions for weight management for pre-diabetes patients. Intervention used existing HIT and standardized DPP curriculum.
Marquard, JL, et al; Int J Med Inform	2013	Overcoming challenges integrating patient-generated data into the clinical EHR: lessons from the controlling disease using inexpensive information technology--hypertension in diabetes (CONDUIT-HID) Project	Examined a low-cost consumer health informatics intervention for patients managing HTN in diabetes: low cost blood pressure monitor, free online app and existing nursing and medical assistant staff.
Massoudi, BL, et al; Healthc (Amst)	2016	Using health information exchanges to calculate clinical quality measures: a study of barriers and facilitators	1/3 of HIEs have capability to report clinical quality measures with another 1/3 planning capability. Completeness and data quality are current barriers, with bright-spots in public health reporting and syndromic surveillance.
Milani, R, et al; Curr Opin Cardiol	2017	Hypertension management in the digital era	Using more frequent blood pressure measurements in conjunction with assessing social determinants of health can provide tailored interventions for HTN control.

Author & Publication	Year Published	Article Title	Brief Description
Ngui, D, et al; J Hypertens	2016	Targeting care gaps in patients with Hypertension: a quality improvement project utilizing electronic medical record hypertension dashboards and a chronic disease coordinator	A quality improvement project utilizing EHR hypertension dashboards and a chronic disease coordinator.
Paul, M., et al; Population Health Management	2015	The state of population health surveillance using EHRs: a narrative review	Gives examples of using EHR data to track indicators and target management efforts. Challenges remain: multiple data sources, data quality and availability, privacy.
Perlman, S., et al; AJPH Surveillance	2017	Innovations in population health surveillance: using EHRs for chronic disease surveillance	Conducted a validation study to compare EHR data to other traditional population-based surveillance surveys (NYC Macroscope and the Primary Care Information Project).
Popovich, M, et al; Online J Public Health Inform	2016	Observations illustrating the use of health informatics to link public health immunization registries and pharmacies to increase adult immunization rates and improve population health outcomes	Case study demonstrating value for pharmacists in access and bi-directional interfaces with state Immunization Information System-Immunization Registries through increased administration of vaccines.
Rahurkar, S, et al; Health Affairs	2015	Despite the spread of HIE, there is little evidence of its impact on cost, use and quality of care	Review of studies into exchanging health information. Majority reported some benefit from HIE, but need for more study to generalize benefits.
Reed, M, et al; Ann Intern Med	2012	Outpatient EHRs and the clinical care and outcomes of Patients with diabetes mellitus	Outpatient EHRs and the clinical care and outcomes of Patients with diabetes mellitus.
Rudin, RS, et al; Am J Manag Care	2016	Knowledge gaps inhibit health IT development for coordinating complex patients' care	Discussions with clinical leaders, technology executives, government officials, and researchers demonstrated current difficulties in HIT for care coordination.
Shelley, D, et al; Am J of Manag Care	2011	Technology-driven intervention to improve hypertension outcomes in community health centers	Case study in New York finding that CDS for hypertension management as part of a broader QI initiative led to substantial rates of hypertension control.

Author & Publication	Year Published	Article Title	Brief Description
Sills, M, et al; J Pediatr	2017	Adding social determinant data changes children's hospitals' readmissions performance	Children's hospital study finding that risk adjustment for SDOH improves readmissions rates and corresponding financial incentives.
Smith, EA, et al; Prev Chronic Dis	2016	Using health information technology and data to improve chronic disease outcomes in federally qualified health centers in Maryland	Describes process of developing data aggregation warehouse and analytics platform to support FQHCs in using pop health data based on standardized clinical quality measures.
Steichen, O, et al; Yearbook of Medical Informatics	2015	HIT coordination to support patient-centered care coordination	Review of select papers covering gaps in practice, HIT system design, and analytics as they relate to care coordination.
Tzeel, A, et al; Am Health Drug Benefits	2012	"Hidden" value: how indirect benefits of health information exchange further promote sustainability	Associated availability of HIE in a hospital emergency department with a reduction in risk of inpatient admission by 28 percent, and Length of Stay for inpatient admits reduced by nearly one day.
Vest, J, et al; Am J of Med Info	2014	The potential for community-based health information exchange systems to reduce hospital readmissions	Accessing patient info in HIE within 30 days of discharge associated with 57% lower odds of readmission. Estimated annual savings of $605,000 for the 6,807 patients in sample.
Warren, J, et al; Stud Health Technol Inform.	2012	Using the general practice EMR for improving blood pressure medication adherence	Intervention in New Zealand using electronic medical record to identify patients and conduct in-person or telephone follow up. Found increased medication possession adherence.
Watts, B, et al; Population Health Alliance	2016	Development and implementation of team-based panel management tools: Filling the gap between patient and population information systems	Veterans Health Administration developed and implemented a population health management tool with intensive stakeholder involvement and a disease specific approach. Covers both diabetes and CVD. Possible to implement even with limited resources.
Wu, FM, et al; J Health Organ Manag	2016	Using health information technology to manage a patient population in accountable care organizations	Survey of state of HIT in early adopters of the accountable care organization model and use of various HIT functionalities in care management.

Appendix B:
Summary of Article Findings

TABLE 1: CLINICAL DECISION SUPPORT

Article	Positive Association	Negative/No Association	More Study Needed
Baig et al: "The Use of Quality Improvement and Health Information Technology to Improve Diabetes Outcomes in African American and Hispanic Patients" (Review)	✓		
Ahmad et al: "Diabetes Prevention, Health Information Technology and Meaningful Use: Challenges and Opportunities" (Review)			✓
Jones et al: "Health Information Technology: An Updated Systematic Review with a Focus on Meaningful Use" (Review)			✓
Hunt et al: "The Impact of a Physician-Directed HIT System on Diabetes Outcomes in Primary Care: A Pre- and Post-Implementation Study"	✓		
Hannon et al: "Effectiveness of Computer Automation for the Diagnosis and Management of Childhood Type 2 Diabetes: A Randomized Clinical Trial"	✓		
Shelley et al: "Technology-Driven to Improve the Hypertension Outcomes in Community Health Centers"	✓		

TABLE 2: COLLABORATIVE CARE

Article	Positive Association	Negative/No Association	More Study Needed
Bauer et al: "Aligning Health Information Technologies with Effective Service Delivery Models to Improve Chronic Disease Care" (Review)	✓		
Rudin et al: "Knowledge Gaps Inhibit Health IT Development for Coordinating Complex Patients' Care"			✓
Cebul et al: "Electronic Health Records and Quality of Diabetes Care"	✓		✓
Steichen et al: "Health Information Technology Coordination to Support Patient-centered Care Coordination"			✓

TABLE 3: PATIENT ENGAGEMENT TOOLS

Article	Positive Association	Negative/No Association	More Study Needed
Buntin et al: "The Benefits of Health information Technology: A Review of the Recent Literature Shows Predominantly Positive Results" (Review)	✓		✓

TABLE 4: SECURE MESSAGING

Article	Positive Association	Negative/No Association	More Study Needed
Kuo et al: "Secure Messaging in Electronic Health Records and Its Impact on Diabetes Clinical Outcomes: A Systematic Review" (Review)	✓		

TABLE 5: DISEASE SELF-MANAGEMENT

Article	Positive Association	Negative/No Association	More Study Needed
Greenwood et al: "A Systematic Review of Reviews Evaluating Technology-enabled Diabetes Self-Management Education and Support" (Review)	✓		

TABLE 6: PATIENT WEB PORTALS

Article	Positive Association	Negative/No Association	More Study Needed
Coughlin et al: "Patient Web Portals, Disease Management, and Primary Prevention" (Review)			✓

TABLE 7: PATIENT GENERATED HEALTH DATA

Article	Positive Association	Negative/No Association	More Study Needed
Marquard et al: "Overcoming Challenges Integrating Patient-Generated Data Into the Clinical EHR: Lessons from the CONtrolling Disease Using Inexpensive IT—Hypertension in Diabetes (CONDUIT-HID) Project"			✓
Bauer et al: "Aligning Health Information Technologies with Effective Service Delivery Models to Improve Chronic Disease Care" (Review)			✓
Greenwood et al: "A Systematic Review of Reviews Evaluating Technology-enabled Diabetes Self-Management Education and Support" (Review)	✓		

TABLE 8: PATIENT EDUCATION

Article	Positive Association	Negative/No Association	More Study Needed
Coughlin et al: "Patient Web Portals, Disease Management, and Primary Prevention" (Review)	✓		✓
Greenwood et al: "A Systematic Review of Reviews Evaluating Technology-enabled Diabetes Self-Management Education and Support" (Review)	✓		✓

TABLE 9: SURVEILLANCE AND TARGETED INTERVENTION

Article	Positive Association	Negative/No Association	More Study Needed
Paul et al: "The State of Population Health Surveillance Using Electronic Health Records: A Narrative Review" (Review)			✓
Perlman et al: "Innovations in Population Health Surveillance: Using EHRs for Chronic Disease Surveillance"			✓
Gabert et al: "Identifying High-Risk Neighborhoods Using Electronic Medical Records: A Population-Based Approach for Targeting Diabetes Prevention and Treatment Interventions"	✓		
Hunt et al: "The Impact of a Physician-Directed HIT System on Diabetes Outcomes in Primary Care: A Pre- and Post-Implementation Study"	✓		
Ma et al: "Translating the Diabetes Prevention Program Lifestyle Intervention for Weight Loss Into Primary Care"	✓		
Reed et al: "Outpatient Electronic Health Records and the Clinical Care and Outcomes of Patients with Diabetes Mellitus"	✓		✓
Green et al: "e-Care for Heart Wellness: A Feasibility Trial to Decrease Blood Pressure and Cardiovascular Risk"	✓		✓
Smith et al: "Using Health Information Technology and Data to Improve Chronic Disease Outcomes in Federally Qualified Health Centers in Maryland"			✓

TABLE 10: COST REDUCTION

Article	Positive Association	Negative/No Association	More Study Needed
Vest et al: "The Potential for Community-Based Health Information Exchange Systems to Reduce Hospital Readmissions"	✓		
Tzeel et al: "'Hidden' Value: How Indirect Benefits of Health Information exchange Further Promote Sustainability"	✓		
Sills et al: "Adding Social Determinant Data Changes Children's Hospitals' Readmissions Performance	✓		
Jones et al: "Health Information Technology: An Updated systematic Review with a Focus on Meaningful Use"			✓
Bu et al: "Benefits of Information Technology-Enabled Diabetes Management"	✓		

TABLE 11: REGISTRIES AND HIE

Article	Positive Association	Negative/No Association	More Study Needed
Rahurkar et al: "Despite the Spread of Health Information Exchange, There is Little Evidence of Its Impact on Cost, Use and Quality of Care" (Review)			✓
Vest et al: "The Potential for Community-Based Health Information Exchange Systems to Reduce Hospital Readmissions"	✓		
Tzeel et al: "'Hidden' Value: How Indirect Benefits of Health Information exchange Further Promote Sustainability"	✓		
Janakiraman et al: "Study on the Effects of Health Information Exchange Access on Healthcare Quality and Efficiency: An Empirical Investigation"	✓		✓
Buntin et al: "The Benefits of Health information Technology: A Review of the Recent Literature Shows Predominantly Positive Results" (Review)	✓		
Popovich et al: "Observations Illustrating the Use of Health Informatics to Link Public Health Immunization Registries and Pharmacies to Increase Adult Immunization Rates and Improve Population Health Outcomes"	✓		

TABLE 12: POPULATION HEALTH MANAGEMENT AND ANALYTICS

Article	Positive Association	Negative/No Association	More Study Needed
Ahmad et al: "Diabetes Prevention, Health Information Technology and Meaningful Use: Challenges and Opportunities" (Review)			✓
Karmali et al: "Risk Scoring for the Primary Prevention of Cardiovascular Disease" (Review)			✓
Chen et al: "Patient Stratification Using Electronic Health Records from a Chronic Disease Management Program"	✓		
Ngui: "Targeting Care Gaps in Patients with Hypertension: A Quality Improvement Project Utilizing EMR Hypertension Dashboards and a Chronic Disease Coordinator"	✓		✓

TABLE 13: SOCIAL DETERMINANTS OF HEALTH

Article	Positive Association	Negative/No Association	More Study Needed
Baig et al: "The Use of Quality Improvement and Health Information Technology to Improve Diabetes Outcomes in African American and Hispanic Patients" (Review)			✓
Milani et al: "Hypertension Management in the Digital Era" (Review)	✓		
Hewner et al: "Integrating Social Determinants of Health into Primary Care Clinical and Informational Workflow During Care Transitions"	✓		
Sills et al: "Adding Social Determinant Data Changes Children's Hospitals' Readmissions Performance	✓		

TABLE 14: MEDICATION SAFETY AND ADHERENCE

Article	Positive Association	Negative/No Association	More Study Needed
Jones et al: "Health Information Technology: An Updated systematic Review with a Focus on Meaningful Use"	✓		✓
Reed et al: "Outpatient Electronic Health Records and the Clinical Care and Outcomes of Patients with Diabetes Mellitus"	✓		
Warren et al: "Using the General Practice EMR for Improving Blood Pressure Medication Adherence"	✓		✓

TABLE 15: REVIEWED STUDIES NOT SEEKING TO DEMONSTRATE FINDINGS

Article	
Adler et al: "Patients in Context – EHR Capture of Social and Behavioral Determinants of Health"	Heisey-Grove et al: "Electronic Clinical Quality Measure Reporting Challenges: Findings from the Medicare EHR Incentive Program's Controlling High Blood Pressure Measure"
Adler-Milstein et al: "Crossing the Health IT Chasm: Considerations and Policy Recommendations to Overcome Current Challenges and Enable Value-Based Care"	Kim et al: "Integrating Health Care for High-Need Medicaid Beneficiaries with Serious Mental Health Illness and Chronic Physical Health Conditions at Managed Care, Provider and Consumer Levels"
Benkert et al: "Diabetes and Hypertension Quality Measurement in Four Safety-Net Sites: Lessons Learned After Implementation of the Same Commercial Electronic Health Record"	Khurshid et al: "Health Information Exchange: Metrics to Address Quality of Care and Return on Investment"
Eden et al: "Barriers and Facilitators to Exchanging Health Information: A Systematic Review" (Review)	Massoudi et al: "Using Health Information Exchange to Calculate Clinical Quality Measures: A Study of Barriers and Facilitators"
Gottlieb et al: "Moving Electronic Medical Records Upstream: Incorporating Social Determinants of Health"	Watts et al: "Development and Implementation of Team-Based Panel Management Tools: Filling the Gap Between Patient and Population information Systems"
Heider et al: "Developing a Community Wide Electronic Health Record Disease Registry in Primary Care Practices: Lessons Learned from the Western New York Beacon Community"	Wu et al: "Using Health Information Technology to Manage a Patient Population in Accountable Care Organizations"

Appendix C:
List of Acronyms

ACI	Advancing Care Information
ACO	Accountable Care Organization
APM	Alternative Payment Model
BP	Blood Pressure
CB-CME	Community-Based Care Management Entity
CDC	Centers for Disease Control and Prevention
CDPH	California Department of Public Health
CDS	Clinical Decision Support
CEHRT	Certified Electronic Health Record Technology
CMS	Center for Medicare and Medicaid Services
CPIA	Clinical Practice Improvement Activity
CPOE	Computerized Physician Order Entry
CVD	Cardiovascular Disease
DHCS	California Department of Health Care Services
DOHMH	NYC Department of Health and Mental Hygiene's
NDPP	National Diabetes Prevention Program
eCQM	Electronic clinical quality measure
ED	Emergency Department
EHR	Electronic Health Record
EMR	Electronic Medical Record
FFS	Fee-For-Service
FQHC	Federally Qualified Health Center
HHP	Health Homes for Patients with Complex Needs

HIE	Health Information Exchange
HIO	Health Information (Exchange) Organization
HIPAA	Health Information Portability and Accountability Act of 1996
HIT	Health Information Technology
HITECH Act	Health Information Technology for Economic and Clinical Health Act
HTN	Hypertension
IHI	Institute for Healthcare Improvement
MIPS	Merit-Based Incentive Payment System
MU	Meaningful Use
NHANES	National Health and Nutrition Examination Survey
PCMH	Patient-Centered Medical Home
PGHD	Patient-Generated Health Data
PHM	Population Health Management
PHR	Personal Health Record
QCDR	Qualified Clinical Data Registry
QI	Quality Improvement
SDOH	Social Determinants of Health
T2D	Type 2 Diabetes
TES	Technology-Enabled Self-Management
WNY	Western New York
WPC	Whole Person Care

Bibliography

Adler NE and Stead WW. (2015) "Patients in context—EHR capture of social and behavioral determinants of health." New England Journal of Medicine, 372(8):698-701. doi:10.1056/NEJMp1413945

Adler-Milstein J, Embi PJ, Middleton B, Sarkar IN, Smith J. (2017) "Crossing the health IT chasm: considerations and policy recommendations to overcome current challenges and enable value-based care." Journal of the American Medical Informatics Association, 24(5):1036-1043. doi:10.1093/jamia/ocx017

Adler-Milstein, J, and Jha, A. (2017) "HITECH Act Drove Large Gains in Hospital Electronic Health Record Adoption." Health Affairs, 36(8):1416-1422. doi:10.1377/hlthaff.2016.1651

Ahmad FS and Tsang T. (2013) "Diabetes prevention, health information technology, and meaningful use: challenges and opportunities." American Journal of Preventive Medicine, 44(4 Suppl 4):S357-63. doi:10.1016/j.amepre.2012.12.020

Badash I, Kleinman N, Barr S, Jang J, Rahman S, Wu BW. (2017) "Redefining Health: The Evolution of Health Ideas from Antiquity to the Era of Value-Based Care." Cureus, 9(2): e1018:1-9. doi:10.7759/cureus.1018

Baig AA, Wilkes AE, Davis AM, Peek ME, Huang ES, Bell DS, Chin MH. (2010) "The use of quality improvement and health information technology approaches to improve diabetes outcomes in African American and Hispanic patients." Medical Care Research and Review, 67(5 Suppl):163S-197S. doi:10.1177/1077558710374621

Bates DW. (2015) "Health Information Technology and Care Coordination: The Next Big Opportunity for Informatics?" Yearbook of Medical Information, 10(1): 11-14. doi:10.15265/IY-2015-020

Bauer AM, Thielke SM, Katon W, Unützer J, Areán P. (2014) "Aligning health information technologies with effective service delivery models to improve chronic disease care." American Journal of Preventive Medicine, 66:167-72. doi:10.1016/j.ypmed.2014.06.017

Benkert R, Dennehy P, White J, Hamilton A, Tanner C, Pohl JM. (2014) "Diabetes and Hypertension quality measurement in four safety-net sites: lessons learned after implementation of the same commercial electronic health record." Applied Clinical Informatics, 5(3):757-772. doi:10.4338/ACI-2014-03-RA-0019

Bernstein W. (2014) "Ten Years In: Charting the Progress of Health Information Exchange in the US." California HealthCare Foundation. http://www.chcf.org/publications/2014/02/ten-years-charting-hie

Berwick DM, Nolan TW, Whittington J. (2008) "The Triple Aim: Care, Health, and Cost." Health Affairs, 27(3):759-769.

Bitton, A., Flier, L., Jha, A. (2012) "Health Information Technology in the Era of Care Delivery Reform: To What End?" Journal of the American Medical Association, 307(24):2593-2594. doi:10.1001/jama.2012.6663

Bu D, Pan E, Walker J, Adler-Milstein J, Kendrick D, Hook JM, Cusack CM, Bates DW, Middleton B. (2007) "Benefits of Information Technology-Enabled Diabetes Management." Diabetes Care, 30(5):1137-1142. doi:10.2337/dc06-2101

Buntin MB, Burke MF, Hoaglin MC, Blumenthal D. (2011) "The benefits of health information technology: a review of the recent literature shows predominantly positive results." Health Affairs, 30(3):464-71. doi:10.1377/hlthaff.2011.0178

Cebul RD, Love TE, Jain AK, Hebert CJ. (2011) "Electronic Health Records and Quality of Diabetes Care." New England Journal of Medicine, 365(9):825-833. doi:10.1056/NEJMsa1102519

Centers for Disease Control and Prevention. National Diabetes Statistics Report, 2017. Atlanta, GA: Centers for Disease Control and Prevention, US Department of Health and Human Services; 2017. https://www.cdc.gov/diabetes/data/statistics/statistics-report.html

Chen R, Sun J, Dittus RS, Fabbri D, Kirby J, Laffer CL, McNaughton CD, Malin B. (2016) "Patient Stratification Using Electronic Health Records from a Chronic Disease Management Program." IEEE Journal of Biomedical Health Information. [Epub ahead of print] doi:10.1109/JBHI.2016.2514264

Coughlin SS, Prochaska JJ, Williams LB, Besenyi GM, Heboyan V, Goggans DS, Yoo W, De Leo G. (2017) "Patient web portals, disease management, and primary prevention." Risk Management in Healthcare Policy, 10:33-40. doi:10.2147/RMHP.S130431

Croft, JB. (2013) "CDC's Public Health Surveillance of Sleep Health." SRS Bull, 19(1):15-17.

Dolin RH and Alschuler L. (2011) "Approaching semantic interoperability in Health Level Seven." Journal of the American Medical Informatics Association, 18:99-103. doi:10.1136/jamia.2010.007864

Eden KB, Totten AM, Kassakian SZ, Gorman PN, McDonagh MS, Devine B, Pappas M, Daeges M, Woods S, Hersh WR. (2016) "Barriers and facilitators to exchanging health information: a systematic review." International Journal of Medical Informatics, 88:44-51. doi:10.1016/j.ijmedinf.2016.01.004

Gabert R, Thomson B, Gakidou E, Roth G. (2016) "Identifying High-Risk Neighborhoods Using Electronic Medical Records: A Population-Based Approach for Targeting Diabetes Prevention and Treatment Interventions." PLoS One, 11(7):e0159227. doi:10.1371/journal.pone.0159227

Go AS, Mozafarrian D, Roger VL, Benjamin EJ, Berry JD, Blaha MJ, Dai S, Ford ES, Fox CS, Franco S, Fullerton HJ, Gillespie C, Hailpern SM, Heit JA, Howard VJ, Huffman MD, Judd SE, Kissela BM, Kittner SJ, Lackland DT, Lichtman JH, Lisabeth LD, Mackey RH, Magid DJ, Marcus GM, Marelli A, Matchar DB, McGuire DK, Mohler ER 3rd, Moy CS, Mussolino ME, Neumar RW, Nichol G, Pandey DK, Paynter NP, Reeves MJ, Sorlie PD, Stein J, Towghi A, Turan TN, Virani SS, Wong ND, Woo D, Turner MB; on behalf of the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. (2013) "Heart disease and stroke statistics—2014 update: a report from the American Heart Association." Circulation, 129:e28-e292. doi:10.1161/01.cir.0000441139.02102.80

Gottlieb LM, Tirozzi KJ, Manchanda R, Burns AR, Sandel MT. (2015) "Moving electronic medical records upstream: incorporating social determinants of health." American Journal of Preventive Medicine, 48(2):215-8. doi:10.1016/j.amepre.2014.07.009

Green BB, Anderson ML, Cook AJ, Catz S, Fishman PA, McClure JB, Reid RJ. (2014) "e-Care for heart wellness: a feasibility trial to decrease blood pressure and cardiovascular risk." American Journal of Preventive Medicine, 46(4):368-377. doi:10.1016/j.amepre.2013.11.009

Greenwood DA, Gee PM, Fatkin KJ, Peeples M. (2017) "A Systematic Review of Reviews Evaluating Technology-Enabled Diabetes Self-Management Education and Support." Journal of Diabetes Science and Technology, 11(5):1015-1027. doi: 10.1177/1932296817713506

Hannon TS, Dugan TM, Saha CK, McKee SJ, Downs SM, Carroll AE. (2017) "Effectiveness of Computer Automation for the Diagnosis and Management of Childhood Type 2 Diabetes: A Randomized Clinical Trial." JAMA Pediatrics, 171(4):327-334. doi:10.1001/jamapediatrics.2016.4207

Heider AR, Maloney NA, Satchidanand N, Allen GM, Mueller R, Gangloff S, Singh R. (2014) "Developing a communitywide electronic health record disease registry in primary care practices: lessons learned from the Western New York beacon community." Egems, 2(3):1089. doi:10.13063/2327-9214.1089

Heisey-Grove DM, Wall HK, Wright JS. (2017) "Electronic clinical quality measure reporting challenges: findings from the Medicare EHR Incentive Program's Controlling High Blood Pressure Measure." Journal of the American Medical Informatics Association. [Epub ahead of print] doi:10.1093/jamia/ocx049

Hewner, S, Casucci, S, Sullivan, S, Mistretta, F, Yuqing, X, Johnson, B, Fox, C. (2017). "Integrating Social Determinants of Health into Primary Care Clinical and Informational Workflow during Care Transitions." Egems, 5(2):1-14. doi:10.13063/2327-9214.1282

Hunt JS, Siemienczuk J, Gillanders W, LeBlanc BH, Rozenfeld Y, Bonin K, Pape G. (2009) "The impact of a physician-directed health information technology system on diabetes outcomes in primary care: a pre- and post-implementation study." Informatics in Primary Care, 17(3):165-174.

Janakiraman, R, Park, E, Demirezen, E, Kumar, S. (2017) "The Effects of Health Information Exchange Access on Healthcare Quality and Efficiency: An Empirical Investigation." Mays Business School Research Paper No. 2915190. https://ssrn.com/abstract=2915190

Jones SS, Rudin RS, Perry T, Shekelle PG. (2014) "Health information technology: an updated systematic review with a focus on meaningful use." Annals of Internal Medicine, 160(1):48-54. doi 10.7326/M13-1531

Karmali KN, Persell SD, Perel P, Lloyd-Jones DM, Berendsen MA, Huffman MD. (2017) "Risk scoring for the primary prevention of cardiovascular disease." Cochrane Database of Systematic Reviews 2017, Issue 3. Art. No.:CD006887. doi:10.1002/14651858.CD006887.pub4

Kim JY, Higgins TC, Esposito D, Hamblin A. (2017) "Integrating Health Care for High-Need Medicaid Beneficiaries With Serious Mental Illness and Chronic Physical Health Conditions at Managed Care, Provider, and Consumer Levels." Psychiatric Rehabilitation Journal, 40(2):207-215. doi:10.1037/prj0000231

Kuo A and Dang S. (2016) "Secure Messaging in Electronic Health Records and Its Impact on Diabetes Clinical Outcomes, A Systematic Review." Telemedicine and e-Health, 22(9):769-777. doi:10.1089/tmj.2015.0207

Khurshid A, Diana ML, Luce SD. (2012) "Health information exchange: metrics to address quality of care and return on investment." Perspectives in Health Information Management, 9:1e.

Ma J, Yank V, Xiao L, Lavori PW, Wilson SR, Rosas LG, Stafford RS. (2013) "Translating the Diabetes Prevention Program Lifestyle Intervention for Weight Loss Into Primary Care." JAMA Internal Medicine, 173(2):113-121. doi:10.1001/2013.jamainternmed.987

Marquard JL, Garber L, Saver B, Amster B, Kelleher M, Preusse P. (2013) "Overcoming challenges integrating patient-generated data into the clinical EHR: lessons from the CONtrolling Disease Using Inexpensive IT—Hypertension in Diabetes (CONDUIT-HID) Project." International Journal of Medical Informatics, 82(10):903-910. doi:10.1016/j.ijmedinf.2013.04.009

Massoudi BL, Marcial LH, Tant E, Adler-Milstein J, West SL. (2016) "Using health information exchanges to calculate clinical quality measures: A study of barriers and facilitators." Healthcare, 4(2):104-8. doi:10.1016/j.hjdsi.2016.04.003

Myers JS and Shannon RP. (2012) "Chasing High Performance: Best Business Practices for Using Health Information Technology to Advance Patient Safety." American Journal of Managed Care, 18(4):e121-e125.

Milani RV, Bober RM, Milani AR. (2017) "Hypertension management in the digital era." Current Opinion in Cardiology, 32(4):373-380. doi:10.1097/HCO.0000000000000405

Ngui D, Qiu MJ, Mann M. (2016) "Targeting care gaps in patients with hypertension: a quality improvement project utilizing EMR hypertension dashboards and a chronic disease coordinator." Journal of Hypertension, 34(Suppl 1):e247-e248.

O'Malley AS, Grossman JM, Cohen GR, Kemper NM, Pham HH. (2010) "Are electronic medical records helpful for care coordination? Experiences of physician practices." Journal of General Internal Medicine, 25(3):177-185. doi:10.1007/s11606-009-1195-2

Paul MM, Greene CM, Newton-Dame R, Thorpe LE, Perlman SE, McVeigh KH, Gourevitch MN. (2015) "The state of population health surveillance using electronic health records: a narrative review." Population Health Management, 18(3):209-16. doi:10.1089/pop.2014.0093

Perlman SE, McVeigh KH, Thorpe LE, Jacobson L, Greene CM, Gwynn RC. (2017) "Innovations in Population Health Surveillance: Using Electronic Health Records for Chronic Disease Surveillance." American Journal of Public Health, (6):853-857. doi:10.2105/AJPH.2017.303813

Popovich M, Altstadter B, Popovich LH. (2016) "Observations Illustrating the Use of Health Informatics to Link Public Health Immunization Registries and Pharmacies to Increase Adult Immunization Rates and Improve Population Health Outcomes." Online Journal of Public Health Informatics, 8(2):e185. doi:10.5210/ojphi.v8i2.6398

Rahurkar S, Vest JR, Menachemi N. (2015) "Despite the spread of health information exchange, there is little evidence of its impact on cost, use, and quality of care." Health Affairs, 34(3):477-83. doi:10.1377/hlthaff.2014.0729.

Rudin RS, Schneider EC, Predmore Z, Gidengil CA. (2016) "Knowledge gaps inhibit health IT development for coordinating complex patients' care." American Journal of Managed Care, 22(9):e317-22.

Shelley D, Tseng TY, Matthews AG, Wu D, Ferrari P, Cohen A, Millery M, Ogedegbe O, Farrell L, Kopal H. (2011) "Technology-driven intervention to improve hypertension outcomes in community health centers." American Journal of Managed Care, 17(12 Spec No.):SP103-10.

Smith EA, Lapinski J, Lichty-Hess J, Pier K. (2016) "Using Health Information Technology and Data to Improve Chronic Disease Outcomes in Federally Qualified Health Centers in Maryland." Prevention of Chronic Diseases, 13:E178. doi:10.5888/pcd13.160445

Steichen O, Gregg W, and Section Editors for the IMIA Yearbook Section on Patient-centered Care Coordination. (2015) "Health Information Technology Coordination to Support Patient-centered Care Coordination." Yearbook of Medical Informatics, 10(1):34-37. doi:10.15265/IY-2015-027

Tzeel A, Lawnicki V, Pemble KR. (2012) ""Hidden" value: how indirect benefits of health information exchange further promote sustainability." American Health Drug Benefits, 5(6):333-41.

Vest JR, Kern LM, Silver MD, Kaushal R; HITEC investigators. (2015) "The potential for community-based health information exchange systems to reduce hospital readmissions." Journal of the American Medical Informatics Association, 22(2):435-42. doi:10.1136/amiajnl-2014-002760

Warren J, Kennelly J, Warren D, Elley CR, Wai KC, Manukia M, Davy J, Mabotuwana T, Robinson E. (2012) "Using the general practice EMR for improving blood pressure medication adherence." Studies in Health Technology Information, 178:228-234.

Watts B, Lawrence RH, Drawz P, Carter C, Shumaker AH, Kern EF. (2016) "Development and Implementation of Team-Based Panel Management Tools: Filling the Gap between Patient and Population Information Systems." Population Health Management, 19(4):232-239. doi:10.1089/pop.2015.0093

Whittington JW, Nolan K, Lewis N, Torres T. (2015) "Pursuing the Triple Aim: The First 7 Years." The Milbank Quarterly, 93(2):263-300.

Wu FM, Rundall TG, Shortell SM, Bloom JR. (2016) "Using health information technology to manage a patient population in accountable care organizations." Journal of Health Organizational Management, 30(4):581-96. doi: 10.1108/JHOM-01-2015-0003