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Electronic Medical Records and Their Use in Health Promotion and Population Research of Cardiovascular Disease

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Abstract The primary use of electronic medical records (EMRs) is to record ongoing interaction between patients and the health systems in which they participate. Secondary uses of the EMR continue to emerge providing opportunities for high-quality population health research as well as health promotion efforts. Research and health promotion activities involving the EMR may be passive and/or active. Secondary EMR activities are being focused on improving patient and provider management of chronic diseases, such as cardiovascular disease (CVD). CVD affects over 30 % of American adults, and the EMR contains information relevant to this multifaceted disease. Secondary EMR use related to CVD research and awareness includes functioning as a data repository, recruiting study participants, building predictive analytics, developing algorithms for disease screening, and delivering disease management tools. Diverse secondary EMR applications have revealed successes, challenges, and limitations highlighting new lessons learned and opportunities in health promotion and population research.

Keywords Electronic medical records · EMR active use · EMR passive use · Electronic health records · Cardiovascular disease · Risk factors · Cardiovascular health · Population research · Health promotion

Introduction

Electronic medical records (EMRs) and electronic health records (EHRs) contain digital information about patient history and medical treatment. EMRs and EHRs allow medical providers to track patient- or practice-level data over time, manage patient care electronically, and theoretically improve quality of care within the healthcare system [1]. The marked difference between the two electronic charting methods surrounds access and portability of the patient record. EMRs tend to be confined to a single healthcare provider, while EHRs have the connotation of patient record mobility across healthcare providers or systems. However, for the purpose of this article, we will use the terms EMR and EHR interchangeably.

Primary uses of EMR include gathering and recording complete and accurate information about a patient's health and treatment and aiding in the provision of care and billing. As the use of EMRs has grown in recent years, secondary uses of the EMR (e.g., for population research and health promotion) have emerged. EMRs may be used actively and/or passively to address highly prevalent diseases such as CVD. For the purposes of this report, "passive use of the EMR" refers to the exclusive use of EHR data for research activities and not actively addressing subsequent results or facilitating interventions. Research utilizing the EMR passively tends to be at a population level with larger sample sizes. Common outcomes

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of EMR passive use include the assessment of CVD prevalence, CVD-related risk factors, and study participant eligibility. Meanwhile, active use of the EMR refers to the use of EHR data for subsequent EMR interactions related to research or health promotion. Research utilizing the EMR actively tends to occur at an individual level with smaller sample sizes. Common outcomes of EMR active use include evidence of enhanced patient care, patient-provider communication, clinical decision support systems (CDSS), and intervention tracking. Passive and active uses of the EMR are not exclusive categories and often overlap. The key difference between passive and active use of the EMR lies in the flow of information. When information only flows out of the EMR, we consider it "passive use"; when information flows both in and out of the EMR, we consider it "active use" (Fig. 1).

Why Cardiovascular Disease?

The population and individual burden surrounding CVD motivates exploratory secondary uses of EMR to solve one of the nation's largest health crises. Over recent decades, great strides have been made to reduce CVD death since its peak in the 1960s, but heart disease remains the leading cause of death in the USA [2, 3]. Over 30 % of deaths in industrialized countries and 25 % of inpatient costs in 2008 were related to CVD [4]. The cost for CVD-related issues was estimated at $450 billion in 2010 and is expected to reach $818 billion by 2030 [3, 5]. These statistics are coupled with suboptimal CVD risk factor control and a need to focus on improving the cardiovascular health (CVH) of all Americans, which shift the framework from risk avoidance to health-promoting behaviors and factors across the lifespan [6, 7]. Increasing CVH can help to reduce CVD [6]. Employing EMR functionality to address CVH is a reasonable next step given the high cost of the disease (both in terms of dollars spent and poor patient outcomes), the differing definitions of CVD, and the chronicity of the disease [4]. Towards focusing on the improvement of CVH to reduce CVD, it is important to note that some EMRs provide built-in patient disease management tools, while others allow for the integration of platform-independent tools that can respond to the complexity of the cardiovascular conditions [8, 9].

EMRs are maturing into required infrastructure for provider- and patient-facing tools for delivering CVH interventions [3]. A review of studies by Roumia and Steinhubl found patient CVD outcomes improved in outpatient and inpatient settings resulting from passive and active EMR interventions [10]. Aspry et al. reviewed 34 randomized controlled trials (RCTs), eight of which used EMRs to intervene in lipid management [11]. Of these eight EMR-based health information technology (HIT) studies, three were determined to have no effect, two increased screening activities, five increased treatment initiation, and two revealed a decrease in low-density lipoprotein cholesterol (LDL-C) levels. As reflected in these studies, EMRs enabled the faster generation and dissemination of study findings related to effective CVH interventions and population research [12•].

Unique EMR Applications for CVD Prevention Research

A review of the literature over the last year revealed a wide range of unique EMR applications for CVD prevention research. Emerging data suggest that more exploration is needed to validate the utility of current CVD biomarkers and further inform risk prediction algorithms [3, 13•]. Several studies sought to enhance clinical preventative services and obtain quality measures to inform patient care [14–16]. Other studies examined EMR-based CVD risk factor management and evaluated intervention programs [3, 7, 17–20]. Additional uses of the EMR included identifying high-risk individuals for targeted CVH interventions [9, 21•, 22••, 23••, 24]. Researchers also integrated disparate data sources within the EMR to provide clinical decision support [8, 25]. Please refer to Table 1 for summaries of these studies which all utilized the EMR in passive and/or active ways. Results of these approaches, whether passive or active, are described in the sections that follow.

Passive Use of EMRs

Several studies seek only to gather EMR information for research without any further use of the EMR itself to engage patients or providers (Fig. 1). EMRs are commonly used to passively identify research samples, conduct CVD population research, and quantify the effect of CVH interventions. EMRs may also function as data repositories or run passive identification algorithms to identify high-risk subpopulations (Table 1). Ferrario et al. used de-identified data from EHRs of cardiovascular centers of excellence for a prospective study [18]. The authors estimated CVD risk factor prevalence and cataloged responses to treatment. Preliminary results showed that the systematic reporting of EMR-captured data coupled with provider feedback improved the control of CVD risk factors. Taking a different perspective on a data repository, Kleinberg et al. examined raw longitudinal EMR data within an urban and rural population to conduct causal analyses of CVD risk factors [13•]. Another passive use of the EMR described in the literature focused on monitoring treatment guideline and CVH intervention adherence, for example, researchers passively tracking changes pertaining to CVD risk factors using EHRs. One such study used EHR data to track aspirin prescriptions among over 130,000 patients for more than 4 years from 33 primary care practices in 11 different clinical organizations across six states [19]. Study results revealed that modified guidelines for aspirin use for known CVD patients remained constant for the selected patient

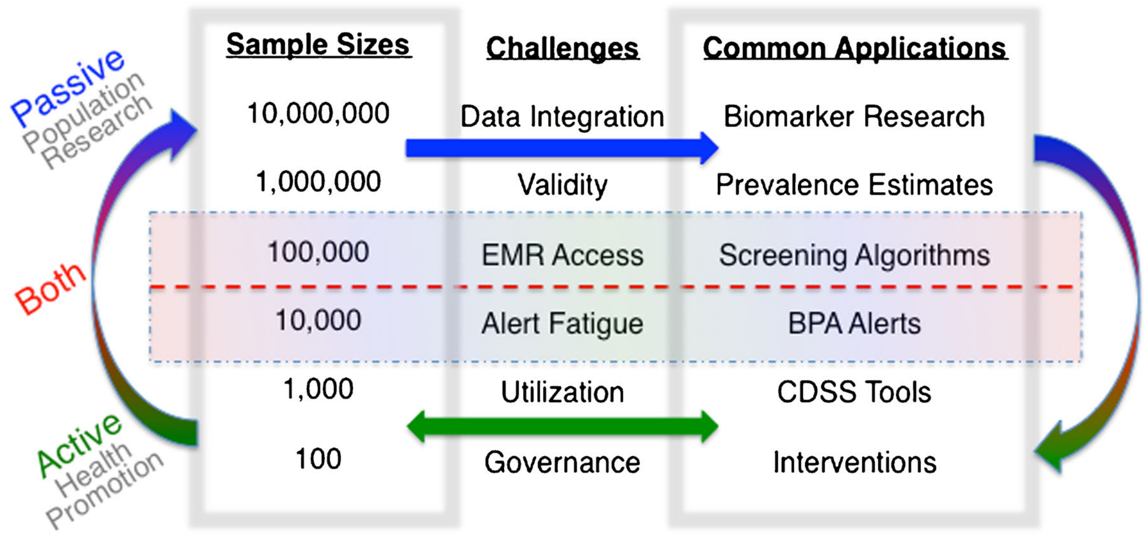

Fig. 1 Passive and active use of electronic medical record information

population. Their study highlighted the ability to examine population-based effects of guideline changes and adherence via EHR data. Danford et al. examined the passive use of an EMR repository in order to assess adherence to lipid management performance metrics, while Hammermeister et al. found that fee-for-service primary care EMR data captured non-controlled blood pressure and cholesterol. Such EMR data can also be used to benchmark guideline adherence [7, 17]. Meanwhile, the Health eHearts program focused on the passive use of EHRs to identify potential patients for study recruitment and enrollment as well as to export quality measures to a secondary database. The extracted data were then used to create quality improvement reports for 25 % of primary care practice-based EHRs in New York City. These innovative passive uses of the EHR were intended to further engage small practice clinicians towards streamlining workflow and improving quality [14, 15]. In the next section, we feature recent success stories in EMR-based CVD population research that used passive approaches.

Successful Approaches in Passive EMR Use

In a US-based study, Cross et al. linked 18,000 unique EMR records to corresponding patient biorepository data to study CVD biomarkers [26]. International studies also exhibited the potential of integrated EMR systems for passive population research. A study in the UK used EMR-linked data stored in four clinical repositories compiled from usual course of care encompassing 225 primary care practices from 1997 to 2010. Study objectives included determination of contemporary associations between blood pressure and 12 specific types of CVD (accounting for blood pressure-lowering interventions), life years lost, prevalence, incidence, and lifetime risk of CVD [23••]. In all, they longitudinally examined data for 1.25 million patients older than 30 years of age who were initially free of CVD. Results of their study compared previously established risks related to associations between blood pressure and CVD and were consistent with smaller studies, but inconsistent with some larger. Their results also revealed that even with treatment through medication, the burden of hypertension is substantial. Their investigation demonstrated the potential for EMR use towards a higher resolution look at previously established associations, generalizable findings for population research related to CVD among a large number of patients, and over a long period of follow-up. These data may produce results that are more representative of a patient population than traditional CVD cohorts.

Meanwhile, a study of a large region in Spain illustrates the potential of assessing CVD prevalence for specific conditions when EMRs are standardized [24]. With an adult population of 4.8 million persons assigned to primary care physicians, the authors included a sample of 1.9 million patients from the highest-quality clinics and accessed 1.6 million medical records containing complete data for 27 health problems including CVD. This study enabled policy makers to determine which diseases of interest were most prevalent and expanded their understanding of population-wide CVH. Another study in Catalonia Spain examined CVD risk factor prevalence and control [22••]. Due to Spain's universal EMR, investigators examined over 2 million patients and determined a 40 % prevalence rate of hypertension and hypercholesterolemia and discovered that 66 % of patients' CVD risk factors were adequately controlled. These studies highlight the possibilities of continuing the push for secondary uses of EMRs for health promotion and population research related to CVH.

Continued Challenges in Passive EMR Use

Challenges associated with the passive use of EMRs center around data access, quality, standardization, and integration.

Table 1 Key publications in the field: study setting, participants, and contribution to the literature

First author, year, and country of source study	Setting	Number of participants	EHR utilization	Outcomes of study
Aspry, 2013, USA	Primary care practices	18,602 patients	Active	HIT lipid interventions
Bardach, 2013, USA	Small primary care practices	297,720 patients	Passive	Improvement of CVD quality measure using incentives
Begum, 2013, USA	Small primary care practices	140 clinicians; (104 completed surveys)	Passive	Piloted *Health eHearts*. CVD quality measures (incentive vs. non-incentive)
Benson, 2013, USA	Primary care	2500 patients	Passive to active	HBC program; identification of CVD risk and management through intervention
Bielinski, 2014, USA	Mayo Clinic	1013 participants	Active	Impact of individualized genomic data influence within provider protocols
Catalan-Ramos, 2013, Spain	Primary care centers	2.1 million participants	Passive	Prevalence, control, and management of CVD
Cohen, 2013, USA	HIT environment	Workshop summary	Passive and active	Synthesized the state of HIT and CVD management
Cross, 2013, USA	Two population-based biospecimen repositories linked with EMRs	18,329 individuals/400 person-years of EHR follow-up	Passive	Biomarker validation via EHR-based repositories
Danford, 2013, USA	Academic primary care clinics	3779 patients with CAD	Passive	Adherence to lipid management performance measures
Ferrario, 2013, USA	Patients of eight cardiovascular centers	87,863 patients	Passive	Understand the value of EMRs in controlling rates of CV risk factors
Foraker, 2014, USA	Primary care clinics	1600 females	Passive to active	Risk management using *SPHERE* visualization tool to improve CVH
Goudev, 2014, USA	Meta-analysis of international studies	51,059 participants	Passive	Understand role of EMR in larger observational studies
Green, 2014, USA	Non-profit group health cooperative	101 individuals	Passive to active	Web-based intervention efforts to lower blood pressure and CVD risk
Hammermeister, 2013, USA	Primary care clinics	368,943 patients	Passive	BP and LDL non-control in EMRs in patients fee-for-service clinics
Hisset, 2014, USA	Primary care practices	131,050 patients	Passive	Aspirin use in patients with known CVD
Kleinberg, 2013, USA	Urban medical center and a rural health system	46,299 patients	Passive	Evaluation of causal relationships using EHRs
Persell, 2013, USA	Nine health centers in Northwestern Access Community Health Network	140 participants	Active	Outpatient medication management for uncontrolled hypertension
Rapsomaniki, 2014, UK	Primary care centers	1.25 million patients	Passive	Association between blood pressure and incident CVD
Roumia, 2014, USA			Passive and Active	Overview of EMR use to improve CV outcomes
Violan, 2013, Spain	Primary care centers	1.6 million patients	Passive	Population health disease prevalence
Wang, 2013, USA	Primary care practices	151 practices	Passive	CVD clinical quality measures with EMR use

BP blood pressure, *CAD* coronary artery disease, *CV* cardiovascular, *CVD* cardiovascular disease, *EHR* electronic health record, *EMR* electronic medical record, *HBC* heartbeat connections, *HIT* health information technology, *LDL* low-density lipoprotein, *SPHERE* stroke prevention in healthcare delivery environments

Passive studies tend to collate EMR data into a central repository or registry which requires extensive work to gather data from multiple sources, reconcile variable, and field discrepancies and verify data quality [7, 19, 23••, 26]. With sample sizes reaching above 2 million, researchers rely on gathering information from practices with the best quality EMR measurements [22••, 23••]. For example, Danford et al. faced difficulty with (1) accurately identifying patients with coronary artery disease (CAD) from the EMR alone, (2) encountering incomplete data on lipid medications, and (3) tracking non-institutional patient treatment [17]. In particular, it was difficult to determine CAD staging from the EMR; and when a manual chart review of 100 random patients without lipid measurement was completed, 63 % of CAD patient records presented sufficient clinical rationale for this lack of information. While possible study results were promising because of the integrated data derived from multiple EHR systems, there were also significant challenges pertaining to provider performance and EHR data accuracy when accounting for contraindications. Challenges still exist for healthcare systems that are unable to integrate data from other EMR systems or for healthcare systems with a patient population that tends to fall in and out of care.

Active Use of EMRs

Some studies use the EMR for research or health promotion activities interactively rather than just for passive information gathering (Fig. 1). Active uses of the EMR might consist of patient- and provider-facing tools, secure messaging and web-based patient interaction, best practice alerts presented to providers to encourage treatment of patients to target goals, risk stratification assessment tools, and clinical decision support tools. Active use of the EMR can involve a mixture of provider- and patient-facing applications. With active use, it is more common in the literature to see smaller sample sizes since EMRs tend to differ from one provider to another. In addition, if active use of the EMR incorporates the transfer of data from provider to patient (or patient to provider), the research will involve additional layers of security and governance issues that can more easily be resolved within, rather than between, academic medical centers.

A successful provider-facing point-of-care tool is the Permanente Online Interactive Network of Tools (POINT), which screens patient data within the EHR every 24 h for undiagnosed CVD. In doing so, the tool calculates a Framingham Risk Score and prompts the provider via a best practice alert to prescribe statins at the patient's next visit [3, 27]. Incorporating the POINT system within the EMR allows for the integration of patient data on allergies, drug-drug interactions, and other diseases. On the back end of this process, the providers are also alerted when patients become non-adherent to their CVD treatment medications, as evidenced by pharmacy data that is also integrated into the EHR.

Another unique provider-facing tool is used by the Health eHearts study, which couples EHR data with incentive programs to improve the quality of CVH intervention activities [14, 15]. For another study, the Mayo Clinic implemented the Right Drug, Right Dose, Right Time program by employing a CDSS to aid providers in genome-guided treatment plans [25]. To achieve the objective of the study, results from clinically actionable genomic blood work were placed within the EMRs of 1013 participants recruited from Mayo Clinic's Biobank. Although results are pending on the aforementioned studies, they open the door for comparative effectiveness studies and improved design for future EMR-based CVD research.

Patient and Provider-Facing Tools

Studies have shown that in systems with EMR capabilities, up to half of the patient population is actively engaged in patient-facing tools. Some patient-facing tools send feedback to patients via secure messages initiated by providers congratulating patients for reducing cholesterol levels or refilling their prescriptions in a timely manner [3]. As a result, patients using these EMR-based tools are more likely to reach target lipid goals [3]. The Persell et al. RCT examined the effect of both patient- and provider-facing EHR-based tools for hypertension medication management [20]. The eligible health center settings were randomized to one of three groups; (1) usual care, (2) EHR-based tools, or (3) EHR-based tools plus nurse intervention. Feedback was provided to patients enrolled in this study using EHR tools such as printed medication lists for patient reference. Study results are pending, but this study demonstrated the potential of EMR use for monitoring hypertension medications.

Roumia and Steinhubl reviewed a study by Samal et al. (2011) which compared blood pressure control among patients seen in outpatient clinics without an EMR, those with an EMR, and those with an EMR and a CDSS [10, 28]. They demonstrated that clinics using the combination of an EMR with CDSS had improved patient outcomes. Using the EMR as a cog in the wheel of multiple active interventions helps to close the loop of care between providers and patients [29].

Continued Challenges

Challenges associated with the active use of EMRs in CVH promotion differ somewhat from those of passive EMR use. Common issues may center on small sample size, lack of tool utilization by providers, and provider "alert fatigue" [30]. A continuing challenge noted in Roumia and Steinhubl's review was an excess of provider-facing alerts. In fact, a survey found that providers within the Veterans' Administration (VA)

Clinical Assessment, Reporting, and Tracking System for Catheterization Laboratories (CART) program received a median of 63 alerts per day. Another challenge related to the active use of EMRs is the gap between data captured by discrete fields versus free text [10]. Cohen et al. found that even with the increase in use of HIT, unstructured and free text data comprises approximately 80 % of information contained within EMRs [3]. Even with the advances in the field of biomedical informatics in natural language processing, extrapolating discrete data from free text data is difficult and remains a challenge to successful population research.

These struggles are echoed in the Foraker et al. study encountering missing data values, data integration issues, and integrated physician use [8]. Specifically, future research efforts may seek to evaluate EMR use by all levels of providers, not just physicians. Despite these setbacks, research applications utilizing EMRs are progressing towards overcoming barriers related to incorporating unstructured data fields, patient-reported outcome data, and overall data integration [29].

Combined Passive and Active EMR Use

To more efficiently and effectively meet the challenges of enacting EMR-based research and health promotion efforts, researchers may consider the use of EMRs to screen and identify participants and subsequently to implement and track CVH interventions (Fig. 1). The HeartBeat Connections study utilized such methods in a population-based demonstration project aimed at reducing myocardial infarctions in rural primary care settings [21•]. Investigators used EMRs to circumvent a common barrier of provider time constraints associated with implementing CVD interventions. EMR data was used to identify residents at risk of developing CVD. These residents were invited to enroll, and residents opting into the study underwent mass screening. Biomedical data values were uploaded into participants' EHRs, and patient-reported outcomes related to diet and exercise were manually entered into an EHR flow sheet. Algorithms were then used to extract data from the EHRs to determine study eligibility. Although the original aim was to use the EMR system for all study-related documentation, it was discovered that the current configuration of the EMR was not suitable and therefore a parallel database was created. The EMR was still used for scheduling appointments and recording final patient outcomes.

Green et al. conducted a RCT to establish the feasibility of a web-based blood pressure and weight control intervention [9]. The EMR was used to passively identify 101 eligible individuals. After being consented, patients went through an in-person screening process to gather missing EMR data and complete patient profiles. Active patient-facing web-based interaction was conducted through secure messaging within the EMR for the remainder of the intervention. Even though statistical power was limited given the small sample size, the study showed the potential to use the EMR both to identify study participants (passive use) and orchestrate intervention efforts (active use).

Another EMR-based study that combined active and passive use of the EMR was the Aspry et al. study, which rated types of lipid-control interventions [11]. The study resulted in lower levels of LDL-C among patients who received a combination of guideline and medication support, alerts, and provider-prompted order entry—all coordinated via EMR. The Ohio State University also initiated a study using the EMR in both an active and passive manner. The ongoing project focuses on actively using the EMR to visually characterize CVH and promote dialog between patients and providers [8]. The intervention is aimed towards women 65 years of age and older who attend the primary care intervention clinic. The intervention is based on the American Heart Association's *Life Simple 7*™ CVH measurement guidelines. When an eligible patient has an appointment, a best practice alert within the EMR is triggered. The intervention visualization then opens concurrently with the EMR and is prepopulated with CVH biometric values. Studies like these represent the push towards using the EMR to affect population and individual change in CVH.

Towards New Study Methodologies: Challenges, Initiatives, and Opportunities

EMR technologies may facilitate CVD interventions, but challenges and limitations still exist. The HeartBeat Connections program and the Kleinberg et al. study display the current double-edged sword of EMRs [13•]. We face a landscape of changing CVD biomarkers, risk factor guidelines, and treatments for the achievement of target CVH goals [21•, 26]. For instance, heart failure has no individual lab value that can be used for an objective diagnosis [13•]. A second challenge involves not only the inability to capture patient-reported outcome data not routinely recorded in the EMR, such as diet, exercise, and psychosocial stress information, but also standardizing these patient-reported outcome values. A third challenge surrounds the tracking of outreach attempts and outcomes within EMRs designed for acute care, especially with patients dropping in and out of healthcare systems. A fourth challenge arises when differing levels of clinical care necessitate distinct uses of EMRs even though patients are part of the same system [13•, 21•]. For example, although health coaches and physician providers may use the same type of EMR within a unified healthcare system, this does not mean that (1) risk factor guidelines are consistent across patient records, (2) data are present for all patients, or (3) providers use the same EMR fields or functionalities. Both the Kleinberg et al. and Benson et al. studies struggled with standardizing CVD diagnosis and staging information derived from EMRs as well as structural differences across EMRs [13•, 21•].

Achieving cross-platform interoperability is still a serious limitation, but the push to join physical activity and diet information to better characterize CVD and promote CVH is on the rise [3, 8]. As these efforts advance and become more comprehensive, a better understanding of improving CVH via EMRs will emerge [3]. Recent studies have shown that attention to run-in time is important for EMR-related interventions. Using the same data extracted from EMRs as Begum et al. and Bardach et al., an independent set of researchers investigated the role of duration of use of EMRs and improvements in CVD quality measures (e.g., antithrombotic therapy, blood pressure control, smoking cessation, and hemoglobin A1c testing) [14, 15]. Although all four CVD quality measures improved across practices over time, they found larger improvements in practices using the EMR for 25 months or more [16]. More HIT platforms are being created to work in conjunction with EMRs to characterize CVH and evaluate multipronged interventions [3, 17].

CVD is an ideal target for prevention efforts, and EMR technologies have not yet been maximized to address the myriad of modifiable CVD risk factors. However, opportunities continue to surface as more applications that work in conjunction with the EMR to promote CVH are developed [8, 9, 20, 21•, 25, 31]. EMRs offer the unique opportunity to efficiently identify, implement, and track interventions for various population segments and patients at CVD risk through active and passive use (Fig. 1) [21•]. It will also remain important to explore data derived from differing populations via EMR, since CVD is expected to continue affecting a large portion of the population and EMRs are still intrinsically heterogeneous [13•].

From a healthcare management standpoint, EMRs can be used to enhance management strategies and maximize buy-in as initiatives in healthcare continue to focus on patient-centered coordinated care via accountable care organizations and medical homes [3]. Towards this end, EMRs have the ability to manage CVD at a population level through the efficient use of extant data [12•]. Recent studies also illustrate the ability of EMR intervention use to assess and streamline provider workflow as well as to enhance provider and patient interactions while accounting for differing health system configurations such as insurance status [15, 16, 20].

Conclusions

Because of the availability and growing secondary use of EMR data, CVH promotion and population-based research methodologies can continue to expand to improve CVD outcomes for patients. From applications that enhance patient-provider communication about CVH to the identification of at-risk populations for CVD, creative uses of active and passive EMR use are beginning to improve the efficiency, effectiveness and outcomes of care, particularly as it relates to preventative and guideline-based care in CVD [8, 10, 20, 21•, 25, 26]. In addition, the growing use of EMR data for population research and health promotion has broader scholarly implications, particularly as it relates to the challenges and opportunities we have described. The benefits and opportunities of leveraging the EMR to improve CVH clearly outweigh the challenges and limitations. Moving forward, we should remain mindful of the passive as well as active functionalities of the EMR in order to maximize the benefit of CVD population research and health promotion.

Compliance with Ethics Guidelines

Conflict of Interest Randi Foraker reports grants from Pfizer, Inc., during the conduct of the study; grants from Pfizer, Inc., outside the submitted work. In addition, Foraker has a patent Electronic medical record web application pending. Bobbie Kite is on grant #T15LM011270-02 through the National Library of Medicine. Wilkister Tangasi, Marjorie Kelley, and Julie Bower have no conflicts of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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