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eHEALTH INITIATIVE

Real Solutions. Better Health.

An Issue Brief on eHealth Tools and Heart Disease Care for Socially Disadvantaged Populations

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Executive Summary

Introduction

Successfully treating heart disease across the continuum requires a number of coordinated care processes and resources involving both the provider and the patient. Patient self-management and education are critical in engaging patients to routinely measure their vital signs (including blood pressure, heart activity, and weight) and follow protocols developed with their provider and a care team that include dietary suggestions, recommended exercise regimens and medication. However, significant health disparities exist that limit the ability of patients to receive, and manage cardiovascular care. Socially disadvantaged populations (defined as those who lack access to primary and specialty care because of low socioeconomic status or geographic barriers in rural areas) are at higher risk of developing heart disease. In addition, the clinical settings that serve these populations also often face unique challenges in creating effective cardiac programs, including:

- Shortage of resources to effectively treat every patient within their catchment area;
- Lack of other center(s) of care within a large geographic area;
- Limited amount of specialty care that can be provided without a connection to a large health system;
- Health literacy, knowledge and education barriers faced by socially disadvantaged patients;
- Geographic barriers and/or lack of patient transportation to a primary care facility; and
- Difficulties with patients' native language; cultural beliefs; and financial barriers.

In cardiac care, the use of health IT has been associated with improvements in the measurement of heart conditions, including blood pressure, heart rate, heart imaging, and secondary risk factors such as lipids and blood glucose. Many of these technologies are patient-centric, enabling a partnership among practitioners, patients and their families to ensure that procedures and decisions respect patients' needs and preferences. These technologies, henceforth known as eHealth tools, can also help redefine care delivery in settings that have limited resources and personnel.

The eHealth Initiative, a non-profit organization whose mission is to research and identify the ways in which health IT can be used to improve the quality, safety and efficiency of healthcare, received a grant from the California HealthCare Foundation in April 2012 to study and review eHealth tools that can improve chronic disease care and control among socially disadvantaged populations. This issue brief is the second in a series of three and describes four domains of technologies identified for cardiac care: **telemedicine, mobile health, patient web portals** and **social media**.

Telemedicine

Telemedicine involves the use of information and communications technology to provide health care services to individuals who are not in close proximity to their provider. The term does not refer to a single technology, but rather a group of technologies that is part of a wider process of care. While a number of health information technologies can be utilized in both private and public medical settings, the use of telemedicine is particularly advantageous for socially disadvantaged populations because it provides greater access to care, communication, disease management, and support. Telecardiology case studies were cited within this study that utilized a number of technical telemedicine approaches within the context of cardiac care, such as videoconferencing, digital cameras, secure messaging, and remote monitoring. Each of these would either transmit patient data directly to a provider in real-time, or would store the data and then forward it to a provider upon request. Examples include:

- **Mobile Telemonitoring in Heart Failure Patients Study (MOBITEL)** tested the impact of a home-based telemonitoring system using internet and mobile phone technology on a sample of 120 heart failure patients participating in the randomized controlled trial. Intervention subjects recorded and transmitted daily vital signs and medication dosage through patient terminals to their physicians, who were subsequently alerted by email in the event of adverse or emergency reports.
- **Insight TeleHealth system (ITSMyHealthFile)** was used at Temple University and Geisinger Medical Center to examine the impact of a telemedicine-supported nurse management program among rural and urban underserved populations. A sample of 465 adults was randomly allocated into an intervention and control group. After one year of surveillance, a significant percent reduction in risk was observed among intermediate and high-risk subjects in the intervention group (19.1%) compared to the usual care group (8.1%), in addition to lower blood lipid and pressure levels overall.

Each of these pilot programs demonstrated sustained reductions in blood pressure and/or the risk of developing cardiovascular disease. The research revealed that telemedicine can increase the accessibility of health services to those who are not in close proximity to a health care provider and to those with limited ability to obtain primary care services in person routinely or easily.

Mobile Health

The use of mobile health devices (mHealth) and applications for chronic disease care has been one of the most significant health IT developments of the past five years. Existing and emerging mHealth technologies, such as smartphone applications; devices with email and text messaging (SMS) functionality; pagers and wireless Internet help facilitate patient self-management of heart disease. These mHealth devices can practically and effectively monitor a patient's status and clinical outcomes while simultaneously increasing patient adherence to treatments. Examples include:

- **Telemedical Interventional Monitoring in Heart Failure (TIM-HF)** trial was a randomized, controlled multicenter study that investigated the impact of remote telemedical management using portable devices among 710 patients with chronic heart failure. Over the course of at least 12 months, 354 intervention subjects measured ECG, blood pressure, and body weight via a personal digital assistant (PDA) that sent automated encrypted transmission via cellphone to the telemedical centers. Hospitalization for heart failure or cardiovascular death was slightly lower among the intervention group, which also showed improved physical functioning.
- **Mobile Phone-Based Telemonitoring for Heart Failure Management** was a randomized controlled trial that used smartphone monitoring via text messaging to transfer real-time vital signs, symptoms, and patient-entered information. Upon transmission, intervention subjects received automated instructions and physicians were alerted in the case of an emergency. Improvements in quality of life, self-care maintenance, and clinical management were observed.

In addition to those comprehensive systems, there are also a number of specific applications that are available for direct download onto a smartphone. A scan of the iPhone, BlackBerry and Android marketplace revealed more than 250 apps that are specifically designed to support the management and monitoring of heart conditions. Examples include:

- **Instant Heart Rate**, which can measure an individual's heart rate after an index finger is placed over a smartphone camera lens for 5-10 seconds. Once measured, the app displays data with a real-time photoplethysmogram and allows information to be shared across a variety of mediums.
- **Heart Age**, which can predict risk of cardiovascular disease using the Framingham 10-Year General Cardiovascular Risk formula that incorporates factors like age, gender, blood pressure, height, weight, and smoking status.
- **Cardiac Assist**, which can track vital signs and medication prescriptions; maintain records of appointments and insurance claims; and offer individuals information regarding cardiovascular conditions.
- **Cardiovascular Medicine Focus Apps**, which can support patient-physician communication and education efforts by providing accurate videos and animated tours of the human body to explain the causes, symptoms, diagnoses, procedures, and risks of heart disease.

Smartphone applications, which have significantly risen in availability over the past year, are the fastest growing sector of the patient-centered tools industry. Given the increase in smartphone adoption within the first and second quarters of 2012, it seems likely that patient-centric technologies will utilize more mobile capabilities. Of the 250 million Americans that own a mobile phone today, 114 million people are using smartphones. Not only are smartphones now the primary handset sold in stores, but the market is evolving into a more mature stage of growth after smartphone penetration grew from 38% to 50.4% over the past year between 2011 and 2012. Although smartphones were initially purchased primarily by more affluent, young, and Caucasian populations during early stages of

adoption, the market has begun to penetrate lower income, elderly, and ethnic minority populations.

Patient Web Portals

Patient web portals (PWPs), which integrate electronic medical records and patient health records, have grown in both significance and popularity over the last five years. These web-enabled systems have the potential to communicate significant amounts of information to a patient as well as increase the efficiency and productivity of care. Examples include:

- The American Heart Association's **HeartHub** is a patient web portal that provides information, tools and resources on cardiovascular disease. The online information resource repository addresses topics on multiple heart diseases and conditions, while providing patients with innovative tools like Heart360, which allows users to track health information and share results directly with their provider.
- Duke Heart Center introduced the **HealthView** Patient Web Portal as part of an ongoing effort to use information technology to further improve patient care and outcomes. The portal offers patients access to tools and applications to help manage their health. Through HealthView, patients can manage prescriptions, track, copy, and print their laboratory results, review their procedure reports and enter vital signs and other data acquired through home-monitoring devices. HealthView also allows patients to view and print their cardiac images from home, making Duke Heart Center the first institution to offer access to this health information.
- The Texas Heart Institute's **Heart Information Center** portal is dedicated to providing educational information related to the prevention, diagnosis, and treatment of cardiovascular disease. The portal features online tools including risk assessments, educational guides, and an index of over 170 heart-health topics. The Heart Information Center's "Ask a Texas Heart Institute Doctor" feature allows patients to submit questions on cardiovascular disease to professional staff members.

Patient web portals have gained tremendous popularity over the past few years, with a number of major health organizations creating and implementing portals for their patient communities. These portals show great promise in facilitating communication between patients and providers, as well as a means of accessing educational materials to assist all populations in the management and care of heart disease.

Social Media

Social media encompasses a wide range of online forums, including blogs, collaborative websites (wikis), social networking sites, photo and video sharing, chat rooms and virtual worlds. Patients are using these channels to gather information about their condition to communicate more effectively with their provider; identify other individuals with similar heart conditions to share clinical information and receive support; and to identify sources of education regarding their disease. Examples include:

- **Inspire**, a social networking site designed by WomenHeart: The National Coalition for Women with Heart Disease to provide a platform for sharing heart disease information, medical and community resources, and networking and support opportunities.
- **Heart Connect**, a social network that empowers people living with heart disease, providing tools and resources for members to discuss and share about relevant treatments, concerns, issues, products, and more. An app has also been developed for users to access remotely with smartphones.

Recent trends suggest that health-related use of social media is higher among socially disadvantaged populations than affluent groups. Despite widespread use, there is a need to study and evaluate the effectiveness of social media on heart disease self-management. The large number of specific social networking communities, blogs, wikis and other platforms have demonstrated the utility of this technology to help patients form support groups, provide educational resources, and share knowledge and best practices in the care and management of heart disease.

Conclusions

Recent advancements in eHealth tools, particularly in the areas of telemedicine, mHealth, patient web portals and social media, show tremendous promise in helping socially disadvantaged populations manage their heart disease.

- **The rate at which mHealth is advancing could significantly impact cardiac care.** Mobile health applications, which have significantly risen in availability over the past year, are the fastest growing sector of the patient-centered tools industry. Given the increase in smartphone adoption in 2012, it seems likely that patient-centric technologies will utilize more mobile capabilities. The development of advanced remote sensors, including wearable devices, will continue to revolutionize the field of telemedicine at large. As smartphones become more ubiquitous, they will expand the reach of telecardiology to harness new technology innovations, support patient engagement, and improve self-management efforts.

- **mHealth and telehealth are viable tools for socially disadvantaged populations**. Research shows that disadvantaged populations have increased access to mobile devices and as smartphones continue to penetrate the market, mHealth will be an effective tool to provide outreach and access to care regardless of an individual's socioeconomic status, race, ethnicity, or geographical location. mHealth can provide vital tools to increase health care access; improve care delivery systems; assist individuals in engaging in culturally competent outreach and education with technology that is easy to use, affordable and scalable, and is already adopted by patients of all ages and socioeconomic status. Effective mHealth can empower patients with heart disease by providing information and education about medications, heart activity, and risk factors; connect patients to communities and

resources; and provide patient advocacy through engagement.

- **Social media is currently underutilized by care providers.** Despite the widespread use of social media by patients, we are unsure of its impact and there is a need to study and evaluate its effectiveness on heart disease management. Specific social networking communities, blogs, wikis and other platforms have demonstrated the utility of this technology to help patients form support groups, access educational resources, and share knowledge and best practices in the care and management of heart disease. However, we did not identify any studies that have evaluated the effectiveness of social media on cardiac care, nor its overall use among socially disadvantaged populations.

- **Patient web portals help educate patients about their heart conditions.** Patient web portals have gained tremendous popularity over the past few years, with a number of major health organizations creating and implementing portals for their patient communities. These portals show great promise in facilitating multilingual communication between patients and providers, as well as a means of accessing educational materials to assist all populations in the management and care of their heart condition.

- **More studies are needed to understand why patients prefer certain tools.** It is not clear what patients "want" or "like." Very few assumptions have been tested with patient populations outside of a controlled experiment. While many of the studies identified in this brief discuss the number and type of patients that utilized eHealth tools, there was little data on patient perceptions of the usability of these technologies. Some research has outlined a few major themes that should be included in the design of any eHealth tool, and a number of the ones included within this brief met most of the criteria. However, it is unclear as to whether patients who participated in a number of these studies found the tools usable and satisfactory for their needs. Studies also generally did not reveal whether the tool was adapted for use by those with low health literacy, those for whom English was not their primary language, and those with limited technical knowledge.

- **Meaningful Use (MU) rules will drive advances not only in the adoption and use of electronic health records (EHRs), but also ultimately spur the integration of eHealth Tools to exchange patient data and improve education, engagement, and communication efforts.** Although many of the measures and requirements of MU Stages 1 and 2 target specific objectives for eligible hospitals and physicians to record, share, and report information via EHRs, there is an underlying emphasis on improving patient access to information and education. For example, MU Stage 1 requires an information infrastructure to provide patient-specific educational resources to at least 10% of a patient population during a reporting period to qualify for payment. MU Stage 2 takes this a step further by requiring at least 10% of patients to view, download, and/or transmit their health

information. Patient-facing technologies such as telemedicine and mHealth can complement provider-centric EHR systems to improve communication, education, and exchange of data among patient populations of all ages, genders, ethnicities, income and education levels, and geographic areas. Moreover, by nature of breaking down traditional barriers to access to care among socially disadvantaged populations, these technologies are likely to continue to grow in importance and use as EHRs are adopted by smaller clinics and hospitals serving low-income populations.

- **Consensus-based standards are needed to accelerate the growth of tools for socially disadvantaged populations**. A number of these eHealth tools use standards that were initially designed for other fields, such as videoconferencing or Internet web pages. However, the use of these standards helps these technologies exchange data on an internal level, so that the appropriate information is received at the point-of-care. On an external level, there is no consensus on standards for these eHealth tools to exchange data with disparate systems. This is a problem that has been inherent within the field of health IT for some time. Although a number of these eHealth tools use common, well-recognized encryption standards for security and represent a low risk to the unauthorized disclosure of personal health information, there is little known about the specific protocols used.

An Issue Brief on the Use of eHealth Tools for Heart Disease Care Among Socially Disadvantaged Populations

Introduction

The effective management of chronic illness requires a close partnership between the patient and the provider. Patients with chronic disease are generally responsible for their own daily care and are often the best source when describing the severity of their symptoms and the efficacy of any treatment. As a result, they must become active participants in their treatment and diligently self-manage their disease. However, compliance with self-management regimens is often poor, usually due to the inability of patients to follow through with instructions, such as – "monitor and track your blood pressure," "reduce your stress levels" and "follow this medication regimen." This problem of adherence, combined with the need to create consistent and bi-directional communication between a patient and a provider, underscores the need for the use of appropriate health information technologies (health IT) to manage chronic disease.

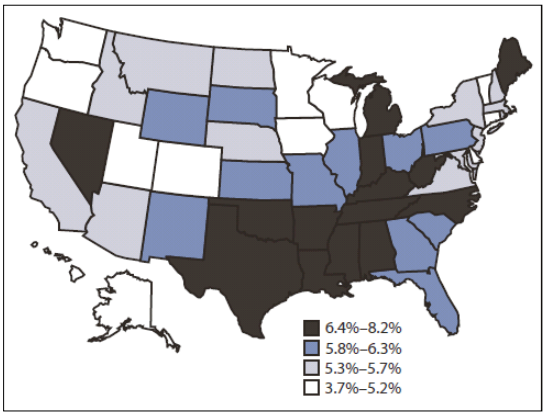
The eHealth Initiative, a non-profit organization whose mission is to drive improvements in the quality, safety and efficiency of healthcare through information and technology, received a grant from the California HealthCare Foundation in April, 2012 to study and review technologies that can improve cardiovascular care and control among socially disadvantaged populations. In follow-up to the first brief examining the above intersection with diabetes, this second brief describes four domains of technologies identified for cardiac care, including: telemedicine, mobile health, patient web portals and social media. A full comprehensive report will be released in January, 2013 that will assess technologies in the following areas:

- evidence of direct impact on heart disease care and control;
- availability and accessibility to socially disadvantaged communities;
- impact on risk factors that are inherent to socially disadvantaged populations;
- usability for patients and/or family, friends, and caregivers;
- cost-effectiveness for physicians, hospitals, health systems, and other healthcare providers;
- ability to exchange data within a large health information system; and
- privacy and security frameworks of each technology to protect personally identifiable health information.

Overview of Heart Disease

Heart disease is the leading cause of death among men and women in the United States and is a major cause of disability. Currently, approximately 595,000 people die of heart disease each year – or to put things in a different perspective, 1 in 4 deaths are caused by heart disease.[1] Coronary heart disease (CHD) is the most common type of heart disease, and can refer to cardiovascular conditions that are generally caused by narrowed, blocked, or hardened coronary arteries restricting the supply of oxygen and blood to the heart. CHD also includes arrhythmia, congenital heart defects, cardiomyopathy, and heart infections, and can result in angina pectoris, stroke, heart failure, and myocardial infarction.[2]

Figure 1: Age-adjusted CHD prevalence among adults (BRFSS 2010).



Approximately 18.5 million Americans have CHD, with prevalence highest in the southeastern states of the U.S. as shown in Figure 1. Although the overall prevalence has decreased over time – most recently from 6.7% to 6.0% between 2006 and 2010 – significant disparities exist across age, gender, state of residence, and socioeconomic status. Prevalence of CHD is greatest among people above the age of 65 years (19.8%), followed by age groups 45-64 years (7.1%) and 18-44 years (1.2%), and remains significantly higher among men (7.8%) than pre-menopausal women (4.6%). Thanks in part to advancements in disease prevention, treatment, and management, the age-adjusted mortality rates for CHD have been steadily declining since the 1960s, and the double drop in both mortality and prevalence suggests that the incidence of CHD is also moribund.[3] However, the crude prevalence of CHD is estimated to sharply increase to 8.6% by 2020 and continue to rise unchecked in the face of an aging population, improved treatment protocols enabling patients with CHD to survive for longer periods of time, and growing prevalence of associated risk factors.

Populations at Risk of Developing Heart Disease

Currently, more than 37% of the general population has multiple modifiable risk factors for heart disease, including sedentary behavior, obesity, high blood pressure and cholesterol, cigarette smoking, diabetes, diet, and stress.[4] Given their susceptibility to these risk factors, socially disadvantaged populations are disproportionately affected by heart disease. These populations can be defined as those who lack access to primary and specialty care because of low socioeconomic status or geographic barriers in rural areas.[5] Among racial/ethnic populations, CHD is most prevalent among American Indians/Alaska Natives (11.6%), followed by African Americans (6.5%) and Hispanics (6.1%), compared to Caucasians (5.8%). CHD is also twice as high among individuals with less than a high school diploma (9.2%) compared to those with a college degree (4.6%). These populations are at a higher risk of developing heart disease not only because of late diagnosis, inadequate control of risk factors and poor management of disease, but also interaction with determinants of

health including insurance, education, employment, food deserts, and neighborhood environments that are not conducive to physical activity.[6] As will be discussed in greater detail, health information technology solutions hold great promise and potential to reduce disparities in heart disease and improve overall health equity.

The Costs and Challenges of Treating Heart Disease

Routinely one of the most expensive conditions to treat, direct coronary heart disease expenditures are estimated to cost the United States $90.9 billion per year, and the American Heart Association expects that by 2030, total direct costs will reach $218.7 billion.[7,8] With more than 4 million people hospitalized due to heart disease each year and an average length of stay of 4.6 days, indirect costs currently account for an additional $68.8 billion ($58.6 billion for lost productivity from mortality and $10.2 billion attributed to morbidity).[9,10] Transitions of care remain a serious cause of concern and hospitalizations continue to constitute a majority of the annual costs associated with heart disease; more than 25% of hospitalized patients with heart failure and 33% of hospitalized patients with acute myocardial infarction are readmitted within 30 days of discharge.[11]

Once patients are discharged with a treatment plan, they fail to receive recommended care approximately 46% of the time and are subject to otherwise preventable complications and/or death. For example, an estimated 37,000 deaths could be prevented each year if heart attack patients received beta blockers or aspirin (currently, only 45% receive beta blockers and only 61% receive aspirin).[12] However, even in the event that patients receive prescriptions, adherence remains a significant obstacle. A recent meta-analysis of more than 376,000 patients observed that only 57% of the individuals were adherent with prescriptions acquired post-discharge, with no significant differences among drug class or age of the patient.[13] Many patients fail to adhere to a prescribed regimen for a variety of reasons, including cost, side effects, belief system, or the sheer challenge of managing the polypharmacy of a chronic disease. Poor adherence can lead to increased medical costs, hospitalizations, and adverse health outcomes that could otherwise have been prevented if patients had complied.

Managing Heart Disease among Socially Disadvantaged Populations

Although there are numerous ways to treat heart disease, including surgery, noninvasive procedures, and a variety of medications, lifestyle and behavior modification can effectively prevent and/or treat forms of heart disease by focusing on weight management, physical activity, smoking cessation, and diet.[14] Indeed, the adequate control of smoking, hypertension and cholesterol alone would reduce annual healthcare costs by as much as $30 billion. [15] By focusing on these problem areas, disease management can reduce hospital readmissions and cardiovascular-related complications, and lead to better health outcomes and overall quality of life.[16] Like other non-communicable diseases that are best treated with the Chronic Care Model, effective cardiac care depends upon the participation and engagement of patients and providers in their respective shared responsibilities, many of which occur beyond the point of care. Successful management of heart disease requires key elements such as coordinated care, patient support and education for self-care, active communication between patients and providers, outcome measurement, and delivery

system support.[17] Patients must measure and monitor indicators such as blood pressure and cholesterol levels at home, and undergo cardiac rehab and prevention regimens that include a combination of medication, diet, stress reduction, and physical activity. Cardiac rehab programs can improve a patient's quality of life and reduce the likelihood of another serious heart event. [18] Because of the proclivity towards developing multiple diseases and complications that both cause and/or result from heart disease, patients must also be regularly screened for associated risk factors such as hypertension, diabetes, asthma, sleep apnea, and overweight.[19] As heart disease is treated across the continuum of care from prevention to treatment to wellness, patients and providers need to communicate frequently about patient health status and care planning at all stages. By maintaining open communication, providers, caregivers, friends, and family members are better able to help individuals cope with their disease and surmount symptoms such as anxiety, depression, denial, and fear.

Often lacking the health literacy and resources required to manage heart disease, socially disadvantaged individuals are prone to unsuccessfully manage their condition due to barriers to access, services, insurance, and comprehensive coverage. Without continuity of care, patients are less likely to understand their condition or address psychosocial issues with their provider, let alone be diagnosed and treated in a timely manner. As a result, socially disadvantaged populations have significantly less accurate perception of risk and knowledge of disease, making vital their education about the prevention, treatment, management, and risks of heart disease to correct their beliefs.[20] Although integrated delivery systems, practices and hospitals are generally able to provide patient-centric services through extended care teams comprised of nurses, patient navigators, physician assistants, and counselors, the resource-limited nature of the safety net settings where many underserved patients seek care demands a different, innovative approach to resolve clinical, administrative, and managerial challenges.

Health Information Technology

Evidence-based interventions can reduce both the risk of and complications from heart disease through medication management, lifestyle coaching, reduction of obesogenic behavior, self-monitoring, and appropriate use of health services. However, as detailed in the previous brief published in this series, these interventions often fail to reach socially disadvantaged populations for a number of reasons, including lower health literacy, geographic and financial barriers, and sociocultural and linguistic difficulties. Health information technology (health IT) has been widely recognized as having the potential to surmount common barriers to cardiac care and provide critical support to patients; enhance changes within healthcare delivery; and provide health providers with timely, secure access to real-time, actionable data to manage health at an individual and population level. In the context of cardiac care, health IT offers numerous benefits and has been associated with improvements in the measurement and monitoring of heart disease, including risk factors such as blood pressure, arrhythmia, cholesterol, and weight, as well as the implementation of guideline-based decision support for providers.

The use of health IT can also support interventions and programs focusing on disease management and wellness. Specifically, health IT has been used to help providers develop and share patient-specific care plans, enhance communication, strengthen the patient-provider relationship and provide access to evidence-based guidelines of care for clinical decision support. Many of these technologies are patient-centric, enabling a partnership among practitioners, patients and their families to ensure that procedures and decisions respect patient needs and preferences.[21] These patient-based technologies, henceforth known as eHealth tools, can also help redefine care delivery in settings that have limited resources and personnel; provide clinicians with necessary information either remotely or directly to assist them in following evidence-based guidelines for care; and may exchange data with larger health information systems to provide information about a patient to multiple providers that may share responsibility for the patient's care. Aiming to provide a more seamless transition between clinical and nonclinical settings of cardiac care, eHealth tools can harness different communication channels, such as telemedicine, mobile health, social media, and patient web portals, to improve the prevention, screening, detection, diagnosis, treatment, monitoring, and management of heart disease. Given the nature of heart disease management, many patient-facing technologies today focus on supporting medication management to improve adherence; lifestyle modification to facilitate behavior change; and remote monitoring systems to track vital signs and provide adverse event alerts and notifications.[22]

Results

Assessing the Technology within the Four Domains of eHealth Tools for Effectiveness with Socially Disadvantaged Cardiac Patients

Telemedicine

Telemedicine has revolutionized the field of cardiology by removing traditional geographic barriers to care and communication by connecting patients and health providers through advanced telecommunication technologies with bi-directional audio and video interaction. Defined as an automated support system for cardiac patients and providers to inform the decision-making process and facilitate disease management, telecardiology can be used in a number of ways to collect, store, and send both objective and subjective data to providers. This can include physiological data, such as blood pressure and cardiac rhythm; laboratory data, such as lipid profiles and non-invasive cardiac activity; behavioral information, such as dietary intake and exercise patterns; medication dosages, interactions and allergies; symptoms of related health complications and conditions; and event data, such as visits to the emergency room. After data is collected and analyzed with clinical decision support software (CDSS) or through consultation with a physician, an appropriate response and care plan can be subsequently operationalized. Telecardiology tools and systems can improve the quality of information sent to providers, improve the frequency and quality of communication between patients and providers; increase patient education and empowerment; reduce the travel time and expenses to consult a provider in-person; and create cost efficiencies due to more accurate treatments and necessary adjustments to patients' care plans.

Telemedicine involves the use of information and communications technology to provide healthcare services to individuals who are not in close proximity to their provider. The term does not refer to a single technology, but rather a group of technologies that is part of wider processes of care across diagnosis, monitoring, and therapy.[23] While a number of health information technologies can be utilized in both private and public medical settings, the use of telemedicine is particularly advantageous for socially disadvantaged populations with heart disease. Telecardiology can increase the accessibility of health services to individuals who are not in close proximity to a healthcare provider or have limited ability to easily seek routine primary care services in person.

Home-based telecardiology applications employ distinct technical approaches for use in the treatment and care of cardiac patients. Synchronous videoconferencing allows a patient to directly interact with a remote provider, nurse, therapist, or counselor, and discuss their health status, concerns, and symptoms. Asynchronous, or store-and-forward systems, can transmit similar captured data onto a server for later view and offline display when providers are not immediately available, or low bandwidth connections prevent the transmission of large swathes of data. To support these approaches and provide high-resolution images of cardiac structure, function, and blood flow, a variety of remote monitoring technologies are employed to capture, store, and transmit specific measurements via wireless electrocardiography and echocardiography (ECG) data.[24]

Innovations in telecardiology have been further spurred by the rise of cardiac implantable devices (apparatuses that are placed in one's chest to assist and/or monitor heart activity). Common devices such as implantable cardiac monitors, pacemakers, cardioverter defibrillators, cardiac resynchronization therapy devices, loop recorders and hemodynamic monitoring devices can facilitate the monitoring and evaluation of cardiac rhythm, blood pressure, and the presence of myocardial ischemia or reduced blood flow to the heart. The continuous stream of real-time data allows health providers to improve the monitoring, treatment, and management of heart disease, and studies have indicated that cardiac implantable devices typically receive high levels of acceptance and satisfaction among both patients and providers. Implantable devices can detect adverse events, send safety alarms, provide global positioning system information in the case of emergency, and reduce the overall volume and cost of follow-up visits.[25] More importantly, the combination of telecardiology and implantable devices is a safe alternative to conventional care that has been found to improve the provision of care and clinical outcomes while reducing the number of hospitalizations associated with heart disease. Information about diet, physical activity and heart activity can be captured through mobile applications on wireless devices and cellular phones to facilitate not only the exchange of electronic data between patients and their respective care team, but also dialogue. By enhancing the frequency, flow, and accuracy of patient-physician communication, telecardiology is an effective means of improving health outcomes and engagement among underserved populations. [26, 27]

A significant number of studies have examined the use of home-based telemedicine in the self-management and control of heart disease, and recent systematic reviews and meta-

analyses suggest their potential to reduce mortality, hospitalization, and adverse symptoms.[28] Given the diversity of studies with different designs, targets, patient populations and healthcare settings, the calculation of an overall effect of telemedicine on cardiac care was not feasible. However, there were several applications of telemedicine that demonstrated a significant effect on cardiac risk factors strongly associated with socially disadvantaged populations, as shown in Table 1.

Table 1: Telecardiology Applications

Application Studied	Effect on Risk Factors
Use of electronic secure messaging to monitor patient-reported symptoms and educate patients about their condition	Improved disease-specific knowledge and adherence with fluid restrictions, daily weighing, physical activity, and alcohol restriction; reduced depression.[29]
Telenursing program through telephone and/or two-way videoconferencing to monitor patient behavior and adherence	Reduced hospital readmissions by 80% and overall length of visit by 300%.[30]
Home telemonitoring program monitored reported symptoms, medication adherence, blood pressure, heart rate, urine output, weight, and a weekly ECG transmission	Increased use of beta blockers at appropriate doses and reduced rate of mortality and hospital readmission among patients; overall healthcare costs were reduced.[31]
Telehealth kiosks installed at senior centers to monitor blood pressure	Increased patient empowerment, self-management and self-monitoring.[32]
Web-based patient health portal to monitor health status and telephone patients as needed	Improved self-care, quality of life, physical activity, and N-terminal prohormone brain natriuretic peptide levels (see footnote[1]).[33]

Two selected case studies from the past five years that demonstrate the impact of telemedicine and its potential clinical effectiveness in heart disease management among socially disadvantaged populations are described below:

1. The **MOBIle TELemonitoring in Heart Failure Patients Study (MOBITEL)** used an open-label randomized control trial design to evaluate the impact of home-based telemonitoring using Internet and mobile phone technology on the outcome of acute worsening of heart failure (acute cardiac decompensation) between 2003 and 2008. A sample of 120 patients between the ages of 18 and 80 years (median age

[1] Brain natriuretic peptide (BNP) and N-terminal prohormone brain natriuretic peptide (NT-proBNP) levels are biochemical markers of left ventricular function and aerobic capacity in heart failure; they are often used to screen, diagnose, and establish prognosis for CHF.

of 66 years) was randomly allocated into an intervention group receiving pharmacological treatment and telemedical surveillance, or into a control group of pharmacological treatment only. Inclusion criteria were acute cardiac decompensation; hospital admission lasting more than 24 hours within four weeks of the intervention; and treatment according to the European Society for Cardiology guidelines. Patients in the intervention group transmitted daily vitals (blood pressure, weight, and heart rate) and medication dosage through mobile phone-based patient terminals to physicians, who were able to maintain continuous access to data via a secure Web portal. In the event that significantly adverse patient-reported vitals were submitted, physicians were automatically sent an alert by email. After six months, there was a 54% reduction of relative risk for re-admission or death among the intervention group. Intervention patients that were hospitalized for deteriorating heart failure were observed to have a significantly shorter length of stay (median of 6.5 days) compared to the control group (10.0 days).[34]

2. Using **Insight TeleHealth's "ITSmyhealthfile" Telemedicine System** (an interactive, internet-based disease management and integrated healthcare delivery system), researchers examined the impact of telemedicine on rural and urban underserved populations at Temple University and Geisinger Medical Center. A sample of 465 subjects between the ages of 18 and 85 years were randomly allocated into a telemedicine-supported nurse management program or usual care (normal nurse management program). Inclusion criteria were a 10% or greater risk of developing cardiovascular disease according to the Framingham 10-Year General Cardiovascular Risk Score formula;[2] exclusion criteria included coronary artery disease, class 3 or 4 heart failure, subjects in nursing homes, and pregnancy. After one year of surveillance, a significant percent reduction in risk was observed among intermediate- and high-risk subjects in the intervention group (19.1%) compared to the usual care group (8.1%), in addition to lower blood lipid and blood pressure levels overall. [35, 36]

Telemedicine has also been used to effectively prevent and/or reduce secondary risk factors such as hypertension among socially disadvantaged populations.[37,38] Below are two examples:

1. Recognizing the proclivity of rural elderly adults dependent upon home care and facilities to age in place, researchers implemented **Technologies for Enhancing Access to Health Management (TEAhM)** to examine the feasibility of nurse-mediated telehealth technology in community-based senior centers located in a rural, underserved area of Southwestern Ohio. Over the course of 10 months, nurses monitored blood pressure data that participants were instructed to measure at least

[2] Using data from the hallmark Framingham Heart Study, the Framingham Risk Score is used to estimate the 10-year risk of an individual for developing cardiovascular disease. The formula incorporates data such as age, gender, blood pressure, and smoking habits to assign individuals a score within the following range: low risk (0-10%), intermediate risk (10-20%), or high risk (20% or more) of developing CHD. The predicted risk score can be used to signal the need for lifestyle changes, education and/or preventive treatment.

once a week. Participants were 55 years or older (median age of 74.1) and had been diagnosed with hypertension that was stabilized with oral therapy. After being trained to use the telehealth kiosk and measure their blood pressure, the intervention group was observed to have a lower mean systolic blood pressure (126mm HG) than the control group (132mm Hg).[39]

2. Recent studies have also demonstrated that nurse-mediated, telephone-based disease management programs are more effective among African American patients when the program is supplanted with a home blood pressure monitoring system. For example, a prospective randomized controlled study was conducted between 2006 and 2007 among a sample population of hypertensive members within an Aetna health maintenance organization plan. A group of 5,932 self-identified African Americans (mean age of 55.7) that had graduated high school and reported a household income under $50,000 were randomly selected. Researchers assessed 638 individuals, 485 of whom completed follow-up assessment over the course of 12 months. In addition to providing intensive outreach, education, and training to patients, the intervention program featured a multimodal disease management program that trained nurse disease case managers in cultural competency, and sent subjects culturally tailored educational materials and lifestyle counseling components. Both the intervention and control group received a wrist cuff monitor to use for home monitoring. The systolic blood pressure adjusted mean was significantly lower among the intervention group (123.6 vs. 126.7 mm HG) compared to the control. The intervention group was also 46% more likely to report weekly monitoring and 50% more likely to have blood pressure under control than the control group.[40]

Based on the studies and information gathered for this report, there is significant interest in utilizing telecardiology among socially disadvantaged populations. The results from the pilot tests cited above indicate this approach is useful for improving clinical outcomes, reducing hospital and emergency department admissions, and lowering costs. Telecardiology tools are well-suited for treating heart disease among underserved populations because they enable the remote measurement, exchange and subsequent interpretation of health data, and can automatically send alerts, notifications, and more. Over time, the technology for communication, data management, and decision support will improve, promising to make telecardiology a useful eHealth tool to improve the quality of care and lower costs for those with heart disease.

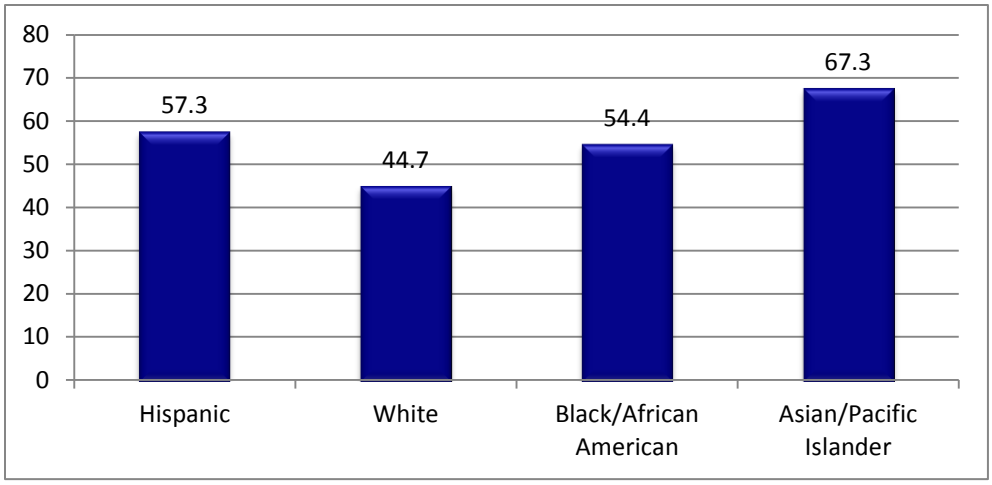
Mobile Health Devices and Applications

The recent proliferation of smartphones has reinvigorated the field of mHealth at large, challenging the once clear-cut definition of a medical device and offering a host of innovations that are rapidly expanding the reach of telecardiology and spurring patient engagement. The ubiquity of mobile communication devices, in conjunction with the Internet, presents a myriad of opportunities to enhance and extend heart disease prevention and management well beyond the reach of traditional care. Representing an evolution from desktop telemedicine to wearable technologies, mHealth can improve the

accessibility of cardiac treatment as well as the ability of patients to actively engage their providers through remote coaching, tracking, feedback, and education. Additionally, the innovations and functionality of mHealth, such as text messaging, smartphone applications and wireless sensor technology, can improve the speed, accuracy, and convenience of diagnostic tests; improve medication adherence and test result delivery; improve interactive, two-way communication; and provide simple methods for data collection, remote diagnosis, emergency tracking and access to health records.[41]

The use of mobile health devices and applications for chronic disease care has been one of the most significant health IT developments of the past five years. Of the 250 million Americans that own a mobile phone today, 114 million people are using smartphones. Not only are smartphones now the primary handset sold in stores, but the market is evolving into a more mature stage of growth after smartphone penetration grew from 38% to 50.4% over the past year between 2011 and 2012. Although smartphones were initially purchased primarily by more affluent, young, and Caucasian populations during early stages of adoption, the market has begun to penetrate lower income, elderly, and ethnic minority populations.[42] As shown in Figure 2 below, a recent *Nielsen Report* observed that ethnic population had a larger increase in smartphone adoption as compared to non-Hispanic whites during the second quarter of 2012:[43]

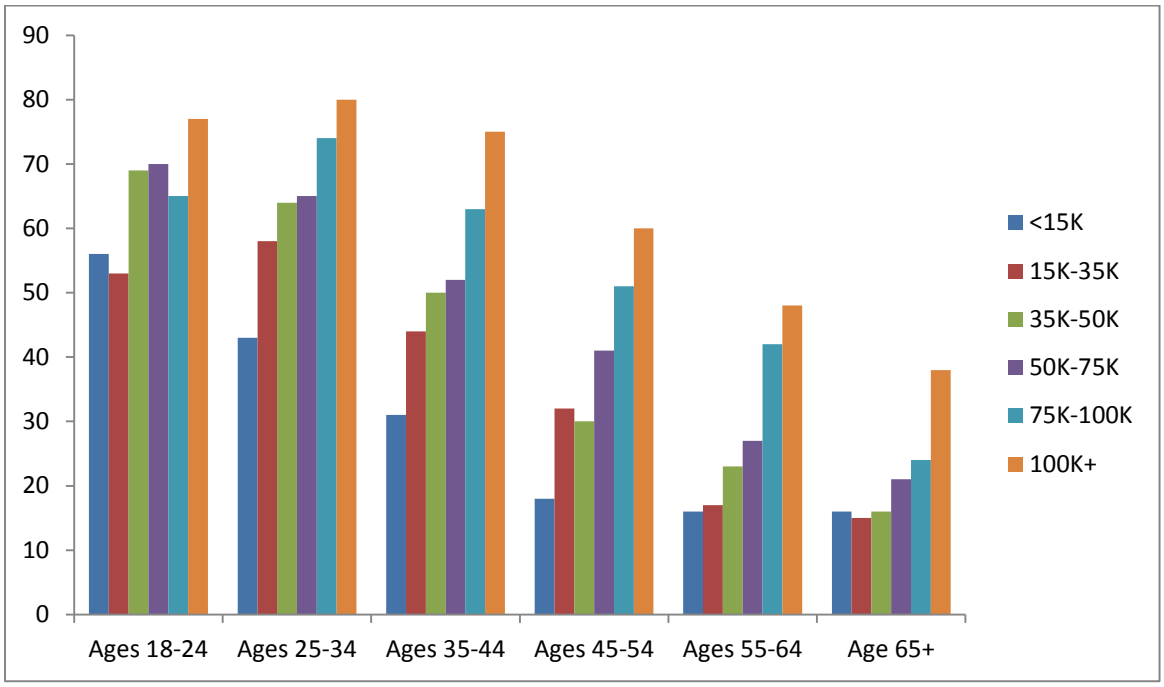
Figure 2: Percentage of Adoption (Q1 2012)



This data suggests that smartphone adoption among Hispanic, African American, and Asian/Pacific Islander populations is growing and over the next several years, the "smartphone divide" will narrow during later stages of market maturity. However, ethnicity is not the only determinant in smartphone ownership. The Nielsen research also indicates that the adoption of smartphones is highest among individuals between the ages of 18-45 and those with incomes higher than $75,000 – but similar to the recent penetration among minority populations, this trend is changing as smartphones are adopted by lower income and older populations. As is shown in Figure 3 on the following page, smartphones are beginning to be adopted by expressly those who stand the most to gain from increased access to internet connectivity, mobile device capabilities, online information, and

interactive multimedia: socially disadvantaged populations.[44] Recent Pew research also suggests that smartphones are following a similar - albeit more nascent - stage of growth among populations in rural areas and/or with no college education. Currently, approximately 29% of rural populations own smartphones (compared to 50% among urban and suburban areas), while 36% of individuals with a high school diploma own smartphones (compared to 61% of those with at least a college degree).[45]

Figure 3: Smartphone Penetration by Age and Income 2012



Existing and emerging mHealth technologies, such as smartphone applications; devices with email and text messaging (SMS) functionality; pagers and the Internet can help facilitate patient self-management of heart disease. These eHealth tools offer effective, practical solutions to monitoring a patient's status and clinical outcomes, while simultaneously increasing patient adherence to regimens and care plans. Cited below are several studies that examined the use of these technologies and indicated significant reductions in hypertension, weight, and blood pressure; improvements in diet and physical activity; and improved health-related outcomes for heart disease patients. The use of mHealth applications and devices may encourage patients to adhere to their regimens by facilitating self-monitoring efforts with reminders and alerts, and serving as simple repositories for information generated by the patient, which can then be shared with the patient's care team. A summary of the types of mHealth applications and their associated functionality is shown in the table below.

Table 2: Overview of Mobile Health Functionalities and Results of Pilot Studies

Functionality	Study Method	Intervention	Results

Smartphone monitoring via text (SMS) messaging; real-time transfer of information	Randomized Controlled Trial	Patients entered vitals and symptoms via mobile phone and subsequently received automated instructions. Email/SMS alerts were sent to physicians, and if warranted, patients received a follow-up call.	Improved quality of life Improved self-care maintenance Improved clinical management [46]
Implantable device and wireless remote monitoring system	Randomized Controlled Trial	Patients that underwent insertion of an implantable cardioverter-defibrillator transmitted automated alerts to clinicians regarding atrial fibrillation and tachycardia activity.	Reduced median time from clinical event to clinical decision from 22 to 4.6 days Reduced length of stay from 4.0 to 3.3 days [47]
Cardiac rehabilitation via 3G mobile phone with built-in accelerometer sensor, camera, and video teleconferencing features	Randomized Controlled Trial	Patients monitored physical activity and diet, synchronizing data to a patient portal and receiving motivational and educational text messages. Telemeetings were held with mentors to revise goals and provide feedback.	Improved adherence (92% compared to 70% in control) Improved physical activity and emotional state Reduction in weight and triglyceride levels[48]

Results from studies of the use of mobile health devices and applications in heart disease care strongly suggest mHealth applications can help patients reduce LDL cholesterol; reduce systolic and diastolic blood pressure; monitor heart rate and activity; and reduce sedentary behavior by encouraging a healthy, active lifestyle through diet and physical activity in patients diagnosed with heart disease.

Several programs have also demonstrated improvements in self-efficacy and adherence to care plans among adults at significant risk of developing or exacerabting cardiovascular conditions. Most mHealth interventions identified in this study require patients to input their health information online, including blood pressure, cholesterol, current medications, weight, height and other information necessary for disease management. A provider, nurse or licensed community health worker would examine and evaluate the information, and send the patient recommendations and reminders via SMS on a regular basis. Intervention periods for these studies typically lasted from two to twelve months. Described below in greater detail are two examples:

1. The **Telemedical Interventional Monitoring in Heart Failure (TIM-HF)** trial was a randomized, controlled multicenter study that investigated the impact of remote telemedical management using portable devices among 710 patients with chronic heart failure. Inclusion criteria included stable ambulatory patients of at least 18 years of age, within the New York Heart Association class II or III, and had a left ventricular ejection fraction of less than 35 percent. Over the course of at least 12 months, 354 intervention subjects measured ECG, blood pressure, and body weight via a personal digital assistant (PDA) that sent automated encrypted transmission via cellphones to the telemedical centers. Follow-up outpatient visits were conducted at three month intervals during the first year and with less frequency the second year, during which patients complete self-administered assessments. Hospitalization for heart failure or cardiovascular death was slightly lower among the intervention group (14.7% compared to 16.5% among the usual care), which also showed improved physical functioning over the study period.[49]
2. A **home-based cardiac rehabilitation program** offered patients the ability to complete a program without traveling to a hospital or gym. Researchers developed a walking-based cardiac rehabilitation program using a smartphone to transmit ECG, heart rate, GPS-based location and speed information via Bluetooth connection to a secure server for remote monitoring. After participating in the six-week program, subjects reported improved physical performance, activity, and mental health, and rated the usability of the system favorably (4.8 on a five-point scale). [50]

Smartphone Applications

In the previous section, several examples were provided that demonstrated the use of mHealth devices as components of a larger telemedicine system for heart disease. In this section, we will discuss the use of smartphone applications in the context of mHealth. As smartphones have penetrated diverse markets and populations over the past several years, the number of applications available for direct download onto smartphones has proliferated in response to the growing interest of the general population. Currently, there are over 40,000 health-related applications and this number is expected to double as the number of smartphone users increases and the sophistication of the technology improves.[51] Despite potential digital literacy barriers, smartphone consumers of all ages and backgrounds have utilized medical apps to support their needs. According to a 2012 Mitchell Poll, 28% of Baby Boomers (adults born between 1946-64) have downloaded between 1-5 apps, and almost half have downloaded six or more. Furthermore, 50% of Boomers with a heart condition

would download a heart disease app, suggesting that the market will continue to grow in popularity and use.[52] As smartphones continue to become more technologically sophisticated with improved processing power and new capabilities, applications will be designed for consumers to monitor and manage their health and care as never before. The evolution of smartphone capabilities and technology has allowed applications to be developed that offer consumers and patients more robust features. Indeed, in the context of heart disease, apps can now monitor heart activity, improve patient-provider communication, manage heart disease, and address risk factors such as diet, physical activity, stress, and tobacco cessation. After scanning for applications specific to heart disease on the three main smartphone devices (iPhone, Android, and Blackberry), we categorized 251 applications according to five critical functions: heart activity (heart rate, cardiograph, etc.), patient-provider communication and education, risk assessment, lifestyle and disease management (physical activity, diet, tobacco, etc.), and vitals (blood pressure, cholesterol, weight). Table 3 displays the segmentation of app categories by percentage.

Table 3: Number and Types of Heart Disease Applications Available by Smartphone Device

Application	Heart Activity	Communication & Education	Risk Assessment	Lifestyle & Disease Management	Vitals	Total
iPhone [53]	8% (9)	22% (24)	16% (18)	28% (30)	26% (28)	109
Android [54]	5% (4)	29% (24)	9% (8)	40% (34)	17% (14)	84
BlackBerry [55]	5% (3)	31% (18)	9% (5)	24% (14)	31% (18)	58

To illustrate these functions, we have selected a number of recently developed applications that are currently being utilized to address factors expressly related to heart disease. By no means an exclusive list, these apps were selected for inclusion given their design features, rating, popularity, ease of use, function, and relevance to the study. Described below are examples of the five categories of application functions

1. **Vital Signs**

   In response to the growing need and desire of cardiovascular patients to measure and record vital signs such as blood pressure, cholesterol, and weight over time, apps have been designed to support disease self-management in a variety of ways. The early waves of cardiovascular apps allowed users to manually enter their blood pressure readings and view graphs illustrating their progress as well as suggestions regarding their health behavior. Today, many apps are more comprehensive in nature, permitting users to automate the recording of sophisticated health indicators. Various universal apps, such as **iBP Blood Pressure**, have been designed to record and analyze weight and blood pressure measured by an external cuff. Cuffs such as Withings' **Blood Pressure Monitor** transmit blood pressure measurements via connection to an iPhone, iPad or iPod, after which data is automatically sent to a database online which patients can access and share with their physicians.[56] Other apps, such as Taconic System's **BP Monitor**, have been designed to monitor blood pressure, weight, medication, and meals to track the effect of changes in regimen. Similarly, **HeartWise** allows individuals to enter their blood pressure readings,

pulse, and weight to calculate arterial pressure and generate graphs showing fluctuations over time.

2. Heart Activity

It is essential that cardiovascular patients are equipped with tools to accurately monitor their heart activity over time, particularly for those with conditions such as arrhythmia, atrial fibrillation, and myocardial ischemia. Unlike blood pressure or body weight measurement, heart rate can be measured directly with iPhone and Android devices by using their cameras to detect a fingertip pulse. Essentially the digital version of a pulse oximeter, apps such as Azumio's **Instant Heart Rate** measure an individual's heart rate after an index finger is placed over a camera lens for 5-10 seconds. Instant Heart Rate displays the data with a real-time photoplethysmogram (PPG),[3] and allows for information to be shared across a variety of mediums.[57] Similarly, MacroPinch's **Cardiograph** can sync with other devices to share and print data, as well as notate location-based measurement.[58] Other apps, such as **DigiFit**, have been designed to work with a variety of external heart rate monitors and fitness sensors.

3. Risk Assessment

The calculation and assessment of risk is critical during not only teachable moments but also throughout the greater continuum of care beginning at early prevention and continuing on into wellness. The earlier that individuals are aware of the risks that behaviors or actions such as smoking or sedentary behavior pose, the more likely they will be able to control risk factors and prolong their likelihood of developing serious complications or cardiovascular conditions. **Wellframe** was recently developed to increase patient engagement by providing preventive care alerts, risk assessment, educational resources and evidence-based information. It also can share information electronically with health providers through email, Direct, or printed reports. Similarly, **Heart Age** and **Heart Risk Calculator** predict risk of cardiovascular disease based on the Framingham 10-Year General Cardiovascular Risk Formula that incorporates factors like age, gender, weight, blood pressure, height, and smoking status.

4. Lifestyle and Disease Management

With each iteration and generation of smartphones that has been introduced to the market, new capabilities have enabled app developers to push the envelope with innovative features. While some of the other categories utilize advancements in wireless connectivity, incorporate external devices or include apps designed around

[3] Photoplethysmogram is a non-invasive circulatory signal that detects variation of blood volume in tissue by illuminating the skin and measuring changes in light absorption and perfusion. Commonly displayed by pulse oximeters and bedside monitors, photoplethysmograms can monitor cardiac output and blood pressure.

components such as camera or dictation, lifestyle and disease management apps have generally taken an integrative approach by bundling a comprehensive package of features together for consumers' day-to-day needs. For example, apps such as **Cardiac Assist** offer patients a one-stop-shop solution by not only tracking vital signs and medication prescriptions, but also maintaining records of appointments and insurance claims as well as offering information regarding cardiovascular conditions. Others focus on more specific areas of heart disease, such as Wombat App's **Cholesterol Manager** allows consumers to track and manage their dietary cholesterol and fat intake. Given the wide-ranging extent of risk factors associated with cardiovascular disease, there are also a variety of apps that target healthy behavior, nutrition, physical activity, sleep, and hypertension – however only those that were expressly designed for heart disease were included in this search. For example, **Sodium One ~ Sodium Counter** and **iFood Diary** offer consumers the ability to track their food intake using an extensive database of items, and **Food Street – Heart Healthy** provides cardiovascular friendly recipes that are low in fat, salt, and cholesterol for individuals with or at risk of heart disease to use in the kitchen.

5. **Patient-Provider Communication and Education**

   Unlike the other aforementioned categories of heart disease apps, many of those providing patient-provider communication and education solutions continue to focus on the basic integration of multimedia and information. A host of encyclopedic apps have been released for patients, medical students and/or providers to use during consultations and at home to explain, illustrate and understand the cardiovascular system through video animations and images. For example, **The Cardiovascular System Pro** offers high-definition, three dimensional images, x-rays and anatomical descriptions, and the **Cardiovascular Medicine Focus Apps** provides accurate videos and animated tours of the human body to explain the causes, symptoms, diagnoses, treatments, procedures, and risks of heart disease. Other apps have been developed with specific functions in mind. For example, **In Case Emergency: Medi Alert** is essentially an advanced version of a medical alert bracelet that contains extensive information on an individual's medical history, conditions, allergies, insurance, and primary care provider in the event of an emergency such as heart failure. On the other side of the spectrum, **Heart Failure Trials** empowers and informs consumers of the latest research and evidence-based medicine related to heart failure.

Although limited research exists regarding the efficacy of smartphone apps, recent studies suggest that they are living up to their promise. A case-control study was conducted among 36 volunteers from an obese clinic to evaluate **SmartDiet**, an app that uses common gamification techniques to educate and encourage a healthy diet and physical activity. [59] Using the exercise and diet plan functions, intervention subjects could calculate the calories consumed during exercise and digested during meals. SmartDiet also featured a diet game which provided a quiz-based learning tool on lifestyle behavior and allowed users to set a

target weight loss goal over the course of six months. Based on the meals and exercise reported, recommendations were regularly displayed regarding caloric intake. After a six-week study period, body composition (weight, BMI, and fat mass) decreased significantly among the intervention group, as shown in table 4 below.

Table 4: Body composition before and after the intervention

Variable	Intervention (*n* = 19)			Control (*n* = 17)		
	Before	After	*t*	Before	After	*t*
Fat mass (kg)	17.3	16.1	2.9 ($p < 0.05$)	16.9	15.7	2.3
Weight (kg)	58.5	56.6	3.6 ($p < 0.05$)	58.3	57.8	0.8
BMI (kg/m^2)	22.2	21.4	3.6 ($p < 0.05$)	22.3	22.1	0.9

The majority of participants rated the accessibility and usability of the system favorably. At the time of publication, a large number of apps are currently being evaluated in trials around the world and results are expected to be published in early 2013.

Patient Web Portals

Patient web portals (PWPs) pull information from existing clinical systems, offering patient and provider access to a comprehensive view of the patient's medical history wherever they can use the Internet. PWPs offer the exciting possibility of truly patient-centered care through robust mechanisms for patient participation in the management of chronic disease. PWPs advance the ability of patients to access and contribute pertinent information relevant to their health, such as diagnoses, immunization and insurance records, medications, allergies, and laboratory results. Health providers and patients can communicate with each other via the patient web portal, which enables meaningful participation by the patient as an equal partner in their care plan and its implementation, as well as opportunities for education and empowerment. Depending on the exact configuration, PWPs may allow for secure access to records so that appointments, health reminders and alerts, prescriptions, referrals, payments, and insurance eligibility and claims can be smoothly updated and/or adjusted by both the health provider and the patient. Recent systematic reviews of PWP-delivered disease management interventions found that PWPs consistently increased satisfaction with care, improved access to health information, enhanced patient-provider communication, and resulted in better overall disease management and patient outcomes.

PWPs have grown in both significance and popularity over the last five years. Part of this is attributable to the ubiquitous nature of the Internet, as well as the growth in interest from both consumers and patients.[60] PWPs can provide secure access to personal health information for an individual, as long as they have an Internet connection. PWPs often offer additional functionality such as the ability to request and create a medical appointment; request medication refills; send and receive messages from a provider, and receive alerts or reminders regarding health status. These web-enabled systems have the potential to

communicate significant amounts of information to a patient as well as increase the efficiency and productivity of care.[61] Moreover, PWPs offer unique opportunities for cardiac patient education and engagement not only during critical teachable moments, but also across the broader continuum of care, including prevention, treatment, disease management, and wellness. By using targeted information resources and risk assessment tools, PWPs have emerged as an innovative way for providers to connect with heart disease patients. However, although PWPs have been implemented in a variety of settings, little research to date has evaluated their efficacy or effectiveness in improving outcomes or patient knowledge. Listed below are several examples of organizations that have developed and/or adopted PWPs for their cardiac patient populations.

1. **Kaiser Permanente HealthConnect** is a large, comprehensive health information system that utilizes a PWP to facilitate communication between a patient and provider using secure messaging. In addition, patients can view their lab results and medications online, as well as portions of their health record. A large percentage of the secure emails sent to providers required a clinical assessment or decision, while another significant proportion required a clinical action.

2. The American Heart Association's **HeartHub** is a patient web portal that provides information, tools and resources on cardiovascular disease. The online information resource repository addresses topics on multiple heart diseases and conditions, while providing patients with innovative tools like Heart360, which allows users to track health information and share results directly with their provider. The My Life Check tool encourages patient engagement through a simple lifestyle assessment.[62]

3. The **Heart and Vascular Center of Arizona (HCVA)** implemented an interactive platform of health IT solutions developed by Kryptic, including Patient Portal. Patient Portal is a comprehensive PWP solution that is scalable to organizational needs, integrating document management, secure messaging, online bill pay, automated clinical reminders, and communication features that meet Meaningful Use criteria for patient engagement to facilitate care transitions. HCVA integrated Patient Portal with its EMR to streamline workflow and improve cost efficiencies associated with the entry and collection of patient health data, medication refills, and patient-physician communication in its cardiac practice.[63]

4. **CardioSmart** is the official patient portal of the American College of Cardiology (ACC). The PWP serves as an extension of the office visit and an opportunity to expand dialogue with patients. CardioSmart features information resources for multiple types of heart disease patients, in addition to educational videos and interactive tools to calculate BMI and assess risk of developing heart disease. Opportunities for patient connections are offered through peer-to-peer support for patients and caregivers.[64]

5. Duke Heart Center introduced the **HealthView** PWP as part of an ongoing effort to use information technology to further improve patient care and outcomes. The portal

offers patients access to tools and applications to help manage their health. Through HealthView, patients can manage prescriptions, track, copy, and print their laboratory results, review their procedure reports and enter vital signs and other data acquired through home-monitoring devices. HealthView also allows patients to view and print their cardiac images from home, making Duke Heart Center the first institution to offer access to this health information.[65]

6. The Texas Heart Institute's **Heart Information Center** portal is dedicated to providing educational information related to the prevention, diagnosis, and treatment of cardiovascular disease. The portal features online tools including risk assessments, educational guides, and an index of over 170 heart-health topics. The Heart Information Center's "Ask a Texas Heart Institute Doctor" feature allows patients to submit questions on cardiovascular disease to professional staff members. In addition to the Heart Information Center, the Texas Heart Institute utilizes St. Luke's Episcopal Hospital's **eCareConnection** portal, which enables patients to request appointments online, send secure messages to their doctor's office, request prescription refills and view test results.[66]

Patient web portals have gained tremendous popularity over the past few years, with a number of major health organizations creating and implementing portals for their patient communities. These portals show great promise in facilitating communication between patients and providers, as well as a means of accessing educational materials to assist all populations in the management and care of their heart disease.

Social Media

Over the past several decades, the Internet has democratized access to information. Today, searching for health information remains the third most popular use of Internet technology; in the United States, it is estimated that health information is sought online by 81 percent of Internet users, with 60 percent of adults reporting that online information has impacted a health-related decision.[67] However, significant disparities emerge among stratified groups. Twenty-nine percent of adults older than 65 look online for health information, compared to 58% of adults between 50-64 years, 66% of adults between 30-49 years, and 71% of adults between 18-29 years. Although women use the Internet for health-related reasons only slightly more than men, significant disparities emerge among disparate education and income groups. Only 62% of adult internet users without a high school diploma gather health information online, compared to 89% of internet users with a college degree. Similarly, 41% of internet users with an income of less than $30,000 gather health information online, compared to 66% of those in the $30,000-$49,999 bracket, 71% in the $50,000-$74,999 bracket, and 87% of those with an income above $75,000. [68]

The vast expanse of the Internet helps individuals perform in-depth information searches; assists consumers with treatment decisions; and prepares them to actively participate in their care. However, as internet access has become more widespread, people have begun to change the way in which they use the Internet. A marked increase in user participation along with content development and management has changed the nature and value of

information online, spurring the development of online communities and social networks. A recent PwC survey found that more than 33% of internet users in the U.S. are using channels such as YouTube, Twitter, and Facebook to find and share medical information, research, symptoms, treatments, drugs, health plans, and treatments.[69] Research has demonstrated that online social support programs targeting chronic illnesses have been shown to reduce adverse symptoms, improve health behaviors and reduce the utilization of healthcare resources. Additionally, these programs have been found to be more effective when communication reaches individuals on an emotional and rational level, or relates to their social or life contexts. Online social media platforms such as Facebook, Twitter, and YouTube, and specialty sites for cardiac patients are incorporating interactive, participatory communication elements within their design and have been enjoying widespread success and penetration among chronic disease e-patient communities.

The eHealth tools and strategies used to both prevent and manage heart disease have changed over the past several years with the emergence of social media. Social media is defined as "a variety of sources of online information that are created, initiated, circulated and used by customers intent on educating each other about products, brands, services, personalities and issues." Social media encompasses a wide range of online forums, including blogs, collaborative websites (wikis) social networking sites, photo and video sharing, chat rooms and virtual worlds.[70] In the last decade, there has been a propensity to deliver Internet-based messages through these media. They have become a major factor in influencing various aspects of consumer behavior including awareness, information acquisition, opinions and attitudes. Although adults are continuing to receive information and care from a health professional, they often turn to friends, families, and fellow patients for psychosocial support and practical advice on coping with day-to-day health solutions. Peer support groups allow patients the opportunity to meet and interact with a community of patients with similar conditions, to share clinical information, and to provide and receive support. Social media can allow these groups to convene in anonymous settings that bypass traditional barriers to peer-to-peer communication, such as stigma, fear, anxiety, shame, trust, and powerlessness.

As static, content-driven websites have evolved towards providing the new dynamic, interactive features of the Internet, patients have more opportunities than ever to benefit from a social network by learning about their illness and gaining support from others with similar experiences. Today, approximately 60% of adult internet users use social network sites in the United States. [71] Age is the most significant determinant of social media use, with younger populations being far more active online than older adults; however, it appears that this correlation may also be related to trust in information posted online. Healthcare consumer engagement and empowerment have matured to the extent that 42% of American adults report having used social media to access health-related consumer reviews, 24% have posted about or updated their health experience, and 16% have shared health-related images or videos. Unlike general online information-seeking trends, there appears to be no disparity in social media behavior when stratifying the population by education level. Moreover, individuals with an income less than $49,999 actually engage in health-related activities using social media more than higher income populations. However,

although social media use is high among Medicaid populations, it is substantially lower among those with Medicare or no health insurance. [72] Broadband connectivity and mobile networks have permitted rural internet users to now be just as likely as urban and suburban areas to have used video-sharing sites such as YouTube. Not only are younger consumers using these sites more actively, but 81% of Hispanics and 76% of African-American populations visit video-sharing websites (compared to 69% of non-Hispanic Caucasians).[73] These trends suggest that culturally appropriate health education and awareness material might be more effectively disseminated via social media for younger, socially disadvantaged populations regardless of their education level. In the context of cardiovascular disease, 23% of internet users with heart conditions report having gone online to find others with similar health concerns (compared to 15% of internet users with no chronic condition have sought similar peer-to-peer help).[74]

To date, the potential influence of social media on heart disease care and management is largely unexplored, despite its extraordinary rise in popularity and use. Research has demonstrated that online social support programs targeting cardiovascular disease have been shown to decrease the prevalence of associated adverse symptoms, and improve health behavior, self-efficacy, and psychosocial quality of life.[75] Through the use of the Internet, social media programs can serve as interactive mediums for providing health information and enhancing social support. Health communication has been observed to be most effective when it reaches people on an emotional and rational level, relates to that person's life, combines mass media and interpersonal communication, is tailored to the individual, and is interactive. Many online social media tools incorporate these communication elements into their design to offer large, educational support groups and virtual communities (such as www.patientslikeme.com and www.curetogether.com), as well as blogs, podcasts, and wikis.

In 2011, a pilot study assessed the feasibility of a novel method of patient-initiated research. [76] Using a social networking site to identify, recruit, and evaluate patients with Spontaneous Coronary Artery Dissection (an extremely rare type of heart disease that can often induce heart attack among predominantly young women), Mayo Clinic researchers were able to recruit 12 participants within a week of IRB approval. With little data available from patient registries or multicenter clinical trials, the Mayo Clinic study sought to begin to fill the gap regarding SCAD etiology, prevalence, recurrence, and management by collecting participants' medical records, images, and demographic information. The rapid enrollment of participants not only reaffirms the ability of social networking and online patient communities to foster patient enthusiasm, but also suggests a cost-effective strategy to build patient registries for rare conditions that would otherwise be expensive to create across multiple centers.

We found no conclusive evidence about the effect of social media on cardiac care or any studies evaluating how these mediums can be leveraged for socially disadvantaged populations. However, Frost and Massagli have indicated that minority populations, specifically non-Hispanic blacks and Native Americans, are more likely to create an online profile on a social networking site, are more willing to use the Internet to research

information about their health, and are more likely to discuss health information online in chat rooms, discussion groups or online support groups, as compared to non-Hispanic whites.[77] These findings suggest that there is untapped potential for using social media and harnessing the interconnected nature of the Internet to improve cardiac care for underserved populations.

While communities around health and cardiac care have become increasingly popular on social media sites, such as Facebook, Twitter and YouTube, other sites have built large, virtual communities specifically around heart disease management. Some examples include:

1. **Inspire** (http://www.inspire.com/) – WomenHeart: The National Coalition for Women with Heart Disease created this social networking site for women with heart disease to provide a platform for sharing heart disease information, medical and community resources, and networking and support opportunities.

2. **Heart Connect** (www.heartconnect.com) is a social network that empowers people living with heart disease, providing tools and resources for members to discuss and share about relevant treatments, concerns, issues, products, and more. An app has also been developed for users to access remotely with smartphones.

3. **The Congenital Heart Information Network** (http://www.tchin.org/) is a national organization providing financial and information resources, advocacy and support to families of children with congenital heart defects and acquired heart disease, and adults with congenital heart defects. The organization promotes relationships among members and visitors through the website, message boards, local support groups, events and promotion of awareness of congenital heart defects.

The pervasive rise of social media suggests that traditional walls of communication will continue to be broken down as healthcare consumers gravitate towards the interactive fabric of web 2.0 and beyond. As health providers, systems, and researchers adapt to the evolving face of the engaged and empowered patient in the 21st century, social media will be incorporated into cardiovascular interventions, treatment, and management protocol, while new theoretical models and frameworks will be developed to better analyze and evaluate their efficacy. Moreover, we believe that social media will offer new opportunities to foster trust, raise awareness, and educate socially disadvantaged populations that have historically experienced a variety of barriers to care, information, and patient-physician communication.

Methodology

We began this study with a comprehensive literature review utilizing the following databases: the Medical Literature Analysis and Retrieval System Online (Medline); PubMed; and the Cumulative Index to Nursing and Allied Health Literature (CINAHL). A search was also conducted through Google Scholar. Searches comprised of various combinations of terms, such as: —(cardiovascular OR heart disease OR cardiology OR heart failure OR arrhythmia OR cardiomyopathy OR heart defect OR artery disease OR myocardial OR angina), —("health it" OR "health information technology" OR "health informatics" OR electronic OR mobile OR digital OR technology OR smartphone OR "mobile application" OR "mobile app" OR "social media"), —(decision support OR "medication management" OR "patient navigation" OR "reminder" OR sensor OR "disease management"), and —(telecardiology OR telemonitoring OR telemedicine OR telehealth OR "electronic health" OR mhealth OR "mobile health"). Relevant references from extracted articles were identified to increase the literature search yield.

Only original studies published after 2005 that evaluated the use of eHealth tools (mobile health applications, telemedicine, social media and patient web portals) for heart disease management in medical practice were reviewed. These included studies using randomized controlled trials, observational (non-randomized controlled trials, pre-post studies, and post-intervention studies) or qualitative methods. Studies evaluating the use of health IT for other chronic diseases and opinion pieces were excluded. In addition, studies evaluating the use of electronic health records or chronic disease registries were excluded as the focus of this project is on patient-centric tools and not on components of health IT that are primarily used by physicians.

Titles and abstracts of selected articles were independently reviewed by two authors and, if found eligible, the full article was then obtained for additional review. When there was disagreement between the two authors about the eligibility of an article, the third author adjudicated the conflict. A total of 514 articles were identified using the above search strategies, with 206 satisfying the inclusion/exclusion criteria. For this report, the studies identified and abstracted were classified based on methodology used, as shown in Table 5:

Table 5: Number and Types of Studies Identified

Study Methodology	Number of Studies
Randomized Controlled Trial	54
Quasi-Experimental Design	24
Observational and Cross-Sectional Studies	25
Feasibility/Case Studies	50
Literature Reviews and Meta-Analyses	53
Total	**206**

Each of the articles was abstracted through a disciplined process to identify the technologies being studied; the results of the utilization of those technologies on cardiac patient outcomes; the relationship between those outcomes and risk factors associated with socially disadvantaged populations; and specific characteristics of each technology, including:

- overall usability of the technology;
- cost of the technology as well as its potential return-on-investment and cost effectiveness;
- data transmission standards to determine its interoperability with larger health information systems; and
- protocols developed within the technology through which personally identifiable information is protected.

Additionally, a non-traditional literature review was conducted through Google to identify specific products that employ the features and functionalities of the eHealth tools identified in the literature review. Information about the development and proliferation of these tools, in addition to projections about their use in the future, were abstracted from online news sources, such as Healthcare Data Management, iHealthBeat, and others.

Key informant interviews were conducted to fill in the identified gaps within the literature. The informants were chosen based on the recommendation of a Technical Advisory Group formed for this project, in addition to specific individuals who were selected based on a review of their articles. A semi-structured interview protocol was designed for this purpose.

Study Limitations

A limitation to this study is the inability to identify research that demonstrates the utility and effectiveness of these eHealth tools on the non-clinical factors associated with heart disease. Particularly amongst socially disadvantaged populations, the need for comprehensive lifestyle changes associated with diet and increased physical activity are paramount in effective management of the disease. However, the vast majority of technology applications found in the research underwent pilot studies that focused specifically on clinical outcomes, with an emphasis on blood pressure and weight. Although other technologies have been evaluated independently in the context of diabetes, sleep apnea, smoking cessation, or other cardiovascular risk factors, few have specifically targeted use among a population with heart disease. Many of the mHealth applications that provided data screens for input on diet and exercise were not evaluated to determine their effectiveness within socially disadvantaged populations. Given the amount of evidence indicating that lifestyle changes are essential for control of heart disease, and that poor nutrition and a sedentary lifestyle are causal risk factors for the study population, additional research is needed to determine the effectiveness of these applications.

Additionally, the demographic characteristics of socially disadvantaged populations indicate a wide array of cultures and ethnicities. Each group has its own distinct culture, beliefs and language when communicating with providers. A significant limitation within the studies found for this brief was the lack of a robust and comprehensive framework to assess

usability. While some research indicated the functionality needed for the acceptance and use of patient-centered applications; very little demonstrated how various cultures could use these applications successfully. Moreover, although smartphone-based programs have generally been effective in improving patient adherence, monitoring, and disease management, the cost of regularly sending and receiving data may remain a significant financial barrier for some socially disadvantaged populations to use mobile devices, not to mention the digital divide in general which may prevent certain subpopulations from fully benefiting from advancements in internet, computer, and mobile technology.

Conclusions

Recent advancements in eHealth tools, particularly in the areas of telemedicine, mHealth, patient web portals and social media, show tremendous promise in helping socially disadvantaged populations manage their heart disease.

- **The rate at which mHealth is advancing could significantly impact cardiac care.** Mobile health applications, which have significantly risen in availability over the past year, are the fastest growing sector of the patient-centered tools industry. Given the increase in smartphone adoption in 2012, it seems likely that patient-centric technologies will utilize more mobile capabilities. Moreover, the development of advanced remote sensors, including wearable devices, will continue to revolutionize the field of telemedicine at large. As smartphones become more ubiquitous, they will expand the reach of telecardiology to harness new technology innovations, support patient engagement, and improve self-management efforts.
- **mHealth and telehealth are viable tools for socially disadvantaged populations**. Research shows that disadvantaged populations have increased access to mobile devices and as smartphones continue to penetrate the market, mHealth will be an effective tool to provide outreach and access to care regardless of an individual's socioeconomic status, race, ethnicity, or geographical location. mHealth can provide vital tools to increase health care access; improve care delivery systems; assist individuals in engaging in culturally competent outreach and education with technology that is easy to use, affordable and scalable, and is already adopted by patients of all ages and socioeconomic status. Effective mHealth can empower patients with heart disease by providing information and education about medications, heart activity, and risk factors; connect patients to communities and resources; and provide patient advocacy through engagement.
- **Social media is currently underutilized by care providers.** Despite the widespread use of social media by patients, we are unsure of its impact and there is a need to study and evaluate its effectiveness on heart disease management. Specific social networking communities, blogs, wikis and other platforms have demonstrated the utility of this technology to help patients form support groups, access educational resources, and share knowledge and best practices in the care and management of heart disease. However, we did not identify any studies that have evaluated the effectiveness of social media on cardiac care, nor its overall use among socially disadvantaged populations.
- **Patient web portals are helping to educate patients about their heart condition.** Patient web portals have gained tremendous popularity over the past few years, with a number of major health organizations creating and implementing portals for their patient communities. These portals show great promise in facilitating multilingual communication between patients and providers, as well as a means of accessing educational materials to assist all populations in the management and care of their heart condition.
- **Meaningful Use (MU) rules will drive advances not only in the adoption and use of electronic health records (EHRs), but also ultimately spur the**

integration of eHealth Tools to exchange patient data and improve education, engagement, and communication efforts. Although many of the measures and requirements of MU Stages 1 and 2 target specific objectives for eligible hospitals and physicians to record, share, and report information via EHRs, there is an underlying emphasis on improving patient access to information and education. For example, MU Stage 1 requires an information infrastructure to provide patient-specific educational resources to at least 10% of a patient population during a reporting period to qualify for payment. MU Stage 2 takes this a step further by requiring at least 10% of patients to view, download, and/or transmit their health information. Patient-facing technologies such as telemedicine and mHealth can complement provider-centric EHR systems to improve communication, education, and exchange of data among patient populations of all ages, genders, ethnicities, income and education levels, and geographic areas. Moreover, by nature of breaking down traditional barriers to access to care among socially disadvantaged populations, these technologies are likely to continue to grow in importance and use as EHRs are adopted by smaller clinics and hospitals serving low-income populations.

- **It is not clear what patients "want" or "like." Very few assumptions have been tested with patient populations outside of a controlled experiment.** While many of the studies identified in this brief discuss the number and type of patients that utilized eHealth tools, there was little data on patient perceptions of the usability of these technologies. Some research has outlined a few major themes that should be included in the design of any eHealth tool, and a number of the ones included within this brief met most of the criteria. However, it is unclear as to whether patients who participated in a number of these studies found the tools usable and satisfactory for their needs. Studies also generally did not reveal whether the tool was adapted for use by those with low health literacy, those for whom English was not their primary language, and those with limited technical knowledge.
- **Consensus-based standards are needed to accelerate the growth of tools for disadvantaged populations.** A number of these eHealth tools use standards that were initially designed for other fields, such as videoconferencing or Internet web pages. The use of these standards helps these technologies interoperate on an internal level, so that the appropriate information is received at the point-of-care. However, on an external level, there is no consensus on standards for these eHealth tools to interoperate with disparate systems. This is a problem that has been inherent within the field of health IT for some time. Although a number of these eHealth tools use common, well-recognized encryption standards for security and represent a low risk to the unauthorized disclosure of personal health information, there is little known about the specific protocols used. None of the studies researched indicated the types of protection that were offered to patients participating in the pilot studies, nor were any specific security protocols referenced.

The transition from acute, episodic and volume-based care towards chronic, coordinated care requires changes within healthcare organizations and the delivery of care. Primary among those changes is the recognition that the patient is at the center of the care effort and is the one responsible for carrying out and monitoring the necessary actions to manage

their heart condition correctly and adequately. With heart disease disproportionately affecting socially disadvantaged populations, there is a fundamental need to provide these individuals with the appropriate tools to empower them to manage their health; create continuous and consistent communication with their provider; and provide resources for them to educate themselves about heart disease and potential care strategies. Critical to this strategy is the use of eHealth tools which can provide Web-based health education; promotion of and support for self-management in community or home-based settings; and adherence to evidence-based clinical procedures and medications. From the information gathered for this brief, it is probable that the technologies used for telemedicine, mobile health applications, patient-web portals and social media can promote partnerships between the patient and providers; facilitate better patient self-management; improve compliance with care protocols and medication management; and reduce the hospital readmission rate among individuals with heart disease.

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