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Electronic Health Records and the Evolution of Diabetes Care: A Narrative Review

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Abstract

Adoption of electronic health records (EHRs) has increased dramatically since the 2009 implementation of the Health Information Technology for Economic and Clinical Health (HITECH) Act. The latest data from the Centers for Disease Control and Prevention (CDC) indicate that the majority of U.S. hospitals and nearly half of U.S. health care professionals have implemented an EHR with advanced functionality.[1] The goals of the HITECH act were not only to incentivize the adoption of EHRs, but also to increase the quality, safety, and efficiency of health care by promoting the concept of "meaningful use."[2,3] The stepwise implementation of "meaningful use" is now entering the latter stages with a focus on improving patient outcomes.[4]

Keywords

Electronic health record, health information technology, primary care, type 2 diabetes

As the prevalence of diabetes approaches 10% in the United States and with an annual cost of over $240 billion, improving the quality of diabetes care through meaningful uses of technology is a national health priority.[5] We are now entering an exciting time in diabetes management as electronic health record (EHR) innovations open up new possibilities for the use of health IT in the primary care of patients with type 2 diabetes. Understanding the successes and unintended consequences of EHRs on the quality of diabetes care can help identify tools and strategies that health care organizations can leverage to improve patient outcomes. In this article, we review a selection of informative studies that demonstrate the impact of EHRs on the quality of diabetes care to date and that illustrate future directions for how EHRs might improve the care of patients with diabetes.

Introduction

For this narrative review, we selected leading articles published over the past decade that examined the clinical impact of EHRs on diabetes care. This review is organized into the following sections: (1) impact of the initial adoption of basic EHRs (including care reminders and registries), (2) newer innovative health IT tools that leverage an underlying EHR infrastructure (eg, secure messaging, online coaching, patient portals), and (3) potential next steps and future avenues of health IT use on quality of diabetes care. Rather than a formal evidence-based summary of the literature, our goal is to provide a conceptual framework for how EHRs—and innovations leveraging EHRs—can be adapted to improve the outpatient care of patients with type 2 diabetes. The reader is referred elsewhere for reviews of technology focused on blood glucose monitoring,[6] in-patient diabetes care,[7] or artificial pancreas.[8] Research articles were drawn primarily from the English language literature and were evaluated by the authors with regard to quality, timeliness, and relevance. Studies with rigorous methodology were preferred, with randomized controlled trials (RCTs, n = 9), large prospective cohort studies (n = 8), and systematic reviews (n = 3) having highest priority.

Basic EHR Implementation and the Quality of Diabetes Care

Several observational studies of the effects of EHRs on large diabetic patient populations have shown significant improvements in quality as measured through reduced hospitalization,

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improved clinical biomarkers, and reduced cost of care.[9,10] This effect is thought to stem from enhanced coordination between health care providers and the ability of EHRs to promote the adoption of organizational guidelines for clinical diabetes care.[10] However, the "real world" experience of new EHR systems often falls short of published results when the implementation is not well coordinated or does not sufficiently involve key stakeholders (eg, the clinicians who must use the new tools).

Two validated EHR-enabled tools that have facilitated these early benefits are diabetes registries and clinical decision support systems.

Diabetes Registries

EHRs provide a structured, comprehensive, and longitudinal patient data set that can be used to continuously track and monitor clinical outcomes on a large scale.[11] As medical practices and health systems become more adept at using EHRs, they can extract and summarize clinical data such as diagnosis codes, pharmacy medication records, and laboratory test results from individual patient records to measure overall quality of care and set clinical benchmarks.[12] These data can then be used to identify specific subpopulations of patients that may require additional organizational resources to improve care.

In the Diabetes Mellitus: Putting Evidence into Practice randomized trial, registry patients with outlying clinical biomarkers and overdue follow-up were identified by a population manager, reminder letters were sent to patients to obtain testing, and primary care providers (PCPs) received standardized messages alerting them to patients who were out of range. This intervention resulted in increased adherence to laboratory testing schedules but did not have a significant impact on glycemic control.[13] Conversely, in a study among patients with poor baseline glycemic control, investigators were able to achieve a small but significant increase in the proportion of patients at target for glycemic control (6.4% increase vs 3.8% increase in control group, $P < .001$) when patients and practitioners were supplied with quarterly diabetes management report cards generated from a patient registry.[14] This inconsistent effect of registries between studies suggests that while improving the organization of information using registries may have some early benefits, systems that already achieve relatively good diabetes control need tools that can help translate the information from registries into clinical action.

Clinical benefits are more likely to be seen when diabetes registries are used to enhanced patient-provider interactions. In an RCT by Stroebel and colleagues,[15] for example, significant reductions in HbA1c, LDL cholesterol, and blood pressure were achieved using data generated from a patient registry to engage patients using a customized health promotion letter. As a population management tool, registries can also improve the coordination of care and follow-up of patients with diabetes, especially those who are in the poorest control and those who have the greatest probability of complications.[12] Though registry-based interventions alone do not always have a significant clinical impact, this population-based approach to care represents a significant advance in care delivery compared to traditional office-based individual patient management.

Clinical Decision Support

Clinical guidelines for optimal management of diabetes are widely available, yet adherence to these guidelines remains variable.[16] Clinical decision support (CDS) systems are designed to guide optimal medical therapy based on individual patient characteristics derived from the EHR.[17] In contrast to registries, CDS can be provided at the point of care when the clinician is with the patient. CDS tools have been developed to provide reminders for routine lab testing, recommendations for specific medication choices, and alerts for potential drug-drug interactions. In an early RCT by Sequist et al,[18] electronic clinical reminders were shown to increase adherence to recommended pharmacotherapy and screening (odds ratio [OR] 1.30, 95% confidence interval [CI] 1.01-1.67), though no clinical outcomes regarding the actual effectiveness of diabetes care were reported. Furthermore, this study indicated that only a minority of clinicians acted on the clinical reminders (less than one-third), implying attenuated CDS efficacy in the face of individual clinician workflows.[18] This is a critically important finding, since poorly implemented and designed tools that do not take provider work flow and clinical needs into account inevitably fail to deliver their full promise of more evidence-based care. Ultimately, while CDS may have some marginal benefits in diabetes care, a knowledge gap by the clinician is rarely the primary reason for patients not reaching goals of glycemic control.

The COMPETE II study by Holbrook et al[19] showed that when decision support was shared by the clinician and the patient through a web-based interface, significant improvements in clinical diabetes care can be achieved. Using a composite outcome of testing and risk factor control based on American Diabetes Association guidelines, patients in this study achieved significant benefit (difference in composite score of 1.27, 95% confidence interval [CI] 0.79-1.75, $P < .001$). These findings underscore a promising application of CDS: creating tools to elicit the patient's input may lead to more effective management changes. This study involved a relatively small cohort of patients, and though the potential of shared CDS systems was observed, incorporating patient input is still difficult despite the increasing digital connectivity of patients. O'Connor et al[20] conducted an RCT that sought to improve the impact of CDS by increasing the specificity of the clinical prompts and creating a clinical workflow, which required providers to acknowledge the CDS prompts before they could close their visit encounter. This study found modestly improved glycemic control (HbA1c: intervention effect –0.26%, CI 95%: –0.06 to –0.47; $P = .01$)

and better maintenance of systolic blood pressure control (80.2% vs 75.1%, $P = .03$), though no improvement in LDL levels were achieved. There exists a fine balance between prompting clinicians to follow guidelines, incorporating patient input, and achieving positive clinical change with CDS systems without misfiring through inability to adapt simple rules to complex patients. One strength of CDS systems is that, when well implemented, these systems lead to higher system-level reliability by requiring explicit definitions of recommended clinical care choices. Overall these CDS systems marginally improve clinical outcomes in diabetes management but are highly dependent on implementation.[21]

Leveraging Advanced EHRs for Innovative Diabetes Care

The organized clinical information in EHRs provides a rich platform on which more advanced functionality can be constructed. One of the primary innovations of more advanced EHRs is the direct engagement of patients with their clinical care data.

Personal Health Records

Recent applications of advanced EHRs have focused on using clinical EHR data in conjunction with the patient-entered information to individualize diabetes care. For example, the EHR can be used to generate interactive content for patients—a personalized health record (PHR)—that can be displayed online and on mobile devices. In more advanced systems, the patient-facing user interfaces of PHRs can be used as 2-way communication channels between the clinician and patient. In an early RCT of this model, patients in the intervention group were given access to a web-based PHR to set goals and develop a "Diabetes Care Plan" prior to their clinical encounter.[22] This intervention was shown to result in a statistically significant increase in medication changes for intervention patients at their next visit (53% vs 15% of visits with medication changes among control patients; $P < .001$). This study represents one of the earliest examples of a PHR reducing patient barriers to medication intensification. A significant limitation of this study, however, was that only a small minority of the overall diabetes population had registered for online portal access, and the patients that had registered tended to have be younger and have better baseline HbA1c. As familiarity and comfort with online activities increases nationwide, including among older patients and those from disadvantaged backgrounds, these PHR-based tools will become increasingly generalizable. Indeed, work by investigators at Group Health, an integrated care system, has found high rates of use by patients with diabetes over age 65.[23] A key insight from this line of research is that one of the most important benefits of advanced patient portal tools is the ability to facilitate visit-independent communication between providers and patients.

EHR-Supported Self-Management

In addition to supporting population-level and visit-based care, the data in EHRs can be used to develop personalized web-based self-management support systems.[24] For example, the recently published Engaging and Motivating Patients Online With Enhanced Resources-Diabetes (EMPOWER-D) study examined the impact of a PHR on clinical interactions and online self-management tools.[25] Various data elements of clinical diabetes care including glucometer readings, dietary intake, and physical activity were digitally tracked and collated into a readily interpretable "Diabetes Status Report." The data in this report were used to engage both a nurse care manager and dietician as well as provide audiovisual content directly to the patients in the intervention group. Significant reductions in HbA1c at 6 months (Intervention: –1.31% vs Usual Care: –0.66%, $P < .001$) were observed, though the difference at 12 months between groups was not significant. This study developed and validated a novel paradigm of primary health care delivery: Data were generated by the patient and gathered digitally, contextualized with patient input and applied to clinical analysis and decision making. It also demonstrated that diabetes can be effectively managed in a *continuous* manner with an ongoing dialogue between the patient and a non-MD health care provider through a PHR populated with patient generated health data. A recent Cochrane systematic review confirmed that computer-based diabetes self-management interventions to manage type 2 diabetes appear to have a small beneficial effect on blood glucose control, with an effect that was larger in studies using mobile phones.[26]

Secure Electronic Messages

Care systems with integrated EHRs also have the potential to support secure electronic messaging between patients and their care team. Electronic communication can save time for the patient, address concerns outside the visit, and be used as a tool to maintain more frequent contacts. In a longitudinal analysis of secure messaging among 6301 adults with diabetes within the Group Health system, for example, investigators found that recent and frequent messaging use was associated with better glycemic control and a higher rate of HbA1c testing adherence, suggesting that secure messaging may facilitate important processes of care and help some patients to achieve or maintain adequate glycemic control.[27] These results were also seen in an analysis of 35 423 people with diabetes and/or hypertension by Zhou et al,[28] that found the use of secure patient-physician email within a 2-month period was associated with an improvement of 2.0-6.5 percentage points in performance on HEDIS measures such as glycemic (HbA1c), cholesterol, and blood pressure screening and control. However, another analysis of a secure messaging implementation found that the increased access provided by secure messaging may have been associated with *increased* subsequent clinical utilization.[29] One possible explanation for this discrepancy may be that newly implemented secure messaging capability uncovers a

previously unmet demand for services that are now more easily accessed. While this may lead to a short-term increased utilization, the hope is that over the long run this will result in a new equilibrium with better overall care.

Peer Navigators

A clear limitation of advanced EHR innovations designed to include patients more directly in their care is that many patients have limited access to, or limited facility with, using such online tools. However, there have been advances in this area as well, such as the development of peer-based teaching using web-based tools, use of clinical personnel trained to help patients use online tools (so-called "electronic navigators" or e-navigators), and even virtual coaches.[30,31] One innovative interweaving of technology with outreach is the ongoing iDecide/Decido study, which uses tailored online diabetes medication decision aids to enable community health workers to provide personalized patient education to underserved Latino and African American adults.[32] Another promising area is the creation of virtual online communities in which patients self-identify and share information, build community, and provide each other with support around living with diabetes.[33]

Unintended Adverse Consequences and Next Steps

Given the high level of complexity and integration required of EHRs and their rapid development and implementation across large patient populations, there remains significant untapped potential in how EHRs are currently used. EHRs are able to generate and store extensive clinical data, which is a strength but also presents challenges for how to most effectively organize and present data for both care team members and patients. PCPs, who are currently the largest source of data input into the EHR, are often overburdened by basic patient data entry and administrative documentation for billing purposes.[34] Advances in EHR applications must account for physician workflow, address real (rather than presumed) needs, and must present information in a way that reduces the number of screen changes and clicks that each clinician must perform to gather relevant data. Unintended adverse consequences of increased EHR use that have been identified include increased work for clinicians, inefficient new workflows, altered communication practices that are less effective, and overdependence on technology.[35] Historically, many new EHR applications have been developed with insufficient provider and patient input. Increased attention to key stakeholders using user-centered design principles is needed to ensure more effective uptake of innovative tools.[36] Moreover, usability for diverse patient populations such as those with limited health literacy is virtually nonexistent. Keeping these concerns in mind when developing and implementing new tools will be critical to supporting more effective dissemination of EHR innovations.

As EHR adoption increases both in breadth of practices and depth of functionality, there are several potential areas for growth. Efficient approaches to integrating patient collected exercise and dietary data into the clinical record may help with lifestyle self-management. Increased tailoring of therapy, management, and self-management will be possible, although data standards for health care sensors, wireless health trackers, and patient generated health data must be established so that data can be assimilated across various platforms. Clinical data such as costs, appointment information, or emergency care that are often isolated in "silos" must be made accessible across providers and across care systems to improve integration of electronically stored clinical information.

Summary

This is an exciting time in diabetes care. Increasingly evidence-based management guidelines are providing a strong clinical base for care, care systems are becoming more integrated, and we are well into the "next generation" of health IT tools designed to support diabetes care. Advances in technology are opening up new alternatives to traditional visit-based management. Further research is now needed to develop, implement, and rigorously evaluate these new health IT-supported care models. Moreover, these new technologies should be implemented in a way that reduces disparities in diabetes care by being accessible and useable by all patients, including Spanish-speaking, low-literacy, and other vulnerable populations who have the greatest need and most to gain from improved diabetes care.

Abbreviations

CDC, Centers for Disease Control and Prevention; CDS, clinical decision support; CI, confidence interval; EHR, electronic health record; HITECH, Health Information Technology for Economic and Clinical Health; OR, odds ratio; PCP, primary care provider; PHR, personalized health record; RCT, randomized controlled trial.

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References

1. US Department of Health and Human Services. More physicians and hospitals are using EHRs than before. Available at: http://www.hhs.gov/news/press/2014pres/08/20140807a.html. Accessed September 2014.
2. Blumenthal D. Implementation of the federal health information technology initiative. *N Engl J Med*. 2011;365:2426-2431. doi:10.1056/NEJMsr1112158.

3. Blumenthal D, Tavenner M. The "meaningful use" regulation for electronic health records. *N Engl J Med*. 2010;363:501-504. doi:10.1056/NEJMp1006114.
4. HealthIT.gov. How to attain meaningful use. Available at: http://www.healthit.gov/providers-professionals/how-attain-meaningful-use. Accessed September 2014.
5. National Diabetes Statistics Report. 2014. Available at: http://www.cdc.gov/diabetes/pubs/statsreport14/national-diabetes-report-web.pdf. Accessed September 2014.
6. Klonoff D. Noninvasive blood glucose monitoring. *Diabetes Care*. 1997;20:433-437. doi:10.2337/diacare.20.3.433.
7. Hsia E, Draznin B. Intensive control of diabetes in the hospital: why, how and what is in the future. *J Diabetes Sci Technol*. 2011;5:1596-1601.
8. Peyser T, Dassau E, Breton M, Skylar J. The artificial pancreas: current status and future prospects in the management of diabetes. *Ann NY Acad Sci*. 2014;1311:102-123.
9. Reed M, Huang J, Graetz I, et al. Outpatient electronic health records and the clinical care and outcomes of patients with diabetes mellitus. *Ann Intern Med*. 2012;157:482-489. doi:10.7326/0003-4819-157-7-201210020-00004.
10. Reed M, Huang J, Brand R, et al. Implementation of an outpatient electronic health record and emergency department visits, hospitalizations, and office visits among patients with diabetes. *JAMA*. 2013;310(10):1060-1065. doi:10.1001/jama.2013.276733.
11. Richesson R. Data standards in diabetes patient registries. *J Diabetes Sci Technol*. 2011;5(3):476-485.
12. Toh M, Leong H, Lim B. Development of a diabetes registry to improve quality of care in the National Healthcare Group in Singapore. *Ann Acad Med*. 2009;38(6):546.
13. Grant RW, Cagliero E, Sullivan CM, et al. A controlled trial of population management: Diabetes Mellitus: Putting Evidence into Practice (DM-PEP). *Diabetes Care*. 2004;27(10):2299-2305. doi:10.2337/diacare.27.10.2299.
14. Fischer HH, Eisert SL, Durfee MJ, et al. The impact of tailored diabetes registry report cards on measures of disease control: a nested randomized trial. *BMC Med Inform Decis Mak*. 2011;11:12. doi:10.1186/1472-6947-11-12.
15. Stroebel RJ, Scheitel SM, Fitz JS, et al. A randomized trial of three diabetes registry implementation strategies in a community internal medicine practice. *Jt Comm J Qual Improv*. 2002;28(8):441-450.
16. McGlynn EA, Asch SM, Adams J, et al. The quality of health care delivered to adults in the United States. *N Engl J Med*. 2003;348:2635-2645.
17. Bright TJ, Wong A, Dhurjati R, et al. Effect of clinical decision-support systems: a systematic review. *Ann Intern Med*. 2012;157:29-43. doi:10.7326/0003-4819-157-1-201207030-00450.
18. Sequist TD, Gandhi TK, Karson AS, et al. A randomized trial of electronic clinical reminders to improve quality of care for diabetes and coronary artery disease. *J Am Med Inform Assoc*. 2005;12(4):431-437. doi:10.1197/jamia.M1788.
19. Holbrook A, Thabane L, Keshavjee K, et al. Individualized electronic decision support and reminders to improve diabetes care in the community (COMPETE II). *CMAJ*. 2009;5, 37-44.
20. O'Connor P, Crain AL, Rush WA, Sperl-Hillen JM, Gutenkauf JJ, Duncan JE. Impact of an electronic medical record on diabetes quality of care. *Ann Fam Med*. 2005;3:300-306.
21. Bryan C, Boren SA. The use and effectiveness of electronic clinical decision support tools in the ambulatory/primary care setting: a systematic review of the literature. *Inform Prim Care*. 2008;16:79-91.
22. Grant RW, Wald JS, Schnipper JL, et al. Practice-linked online personal health records for type 2 diabetes mellitus: a randomized controlled trial. *Arch Intern Med*. 2008;168(16):1776-1782. doi:10.1001/archinte.168.16.1776.
23. Weppner WG, Ralston JD, Koepsell TD, et al. Use of a shared medical record with secure messaging by older patients with diabetes. *Diabetes Care*. 2010;33(11):2314-2319. doi:10.2337/dc10-1124.
24. Walker E, Shmukler C, Ullman R, Blanco E, Scollan-Koliopoulus M, Cohen HW. Results of a successful telephonic intervention to improve diabetes control in urban adults: a randomized trial. *Diabetes Care*. 2011;34:2-7.
25. Tang PC, Overhage JM, Chan AS, et al. Online disease management of diabetes: Engaging and Motivating Patients Online With Enhanced Resources-Diabetes (EMPOWER-D), a randomized controlled trial. *J Am Med Inform Assoc*. 2013;20(3):526-534. doi:10.1136/amiajnl-2012-001263.
26. Pal K, Eastwood SV, Michie S, et al. Computer-based diabetes self-management interventions for adults with type 2 diabetes mellitus. *Cochrane Database Syst Rev*. 2013;3:CD008776. doi:10.1002/14651858.CD008776.pub2.
27. Harris LT, Koepsell TD, Haneuse SJ, Martin DP, Ralston JD. Glycemic control associated with secure patient-provider messaging within a shared electronic medical record: a longitudinal analysis. *Diabetes Care*. 2013;36(9):2726-2733. doi:10.2337/dc12-2003.
28. Zhou YY, Kanter MH, Wang JJ, Garrido T. Improved quality at Kaiser Permanente through e-mail between physicians and patients. *Health Aff (Millwood)*. 2010;29(7):1370-1375. doi:10.1377/hlthaff.2010.0048.
29. Palen TE, Ross C, Powers JD, Xu S. Association of online patient access to clinicians and medical records with use of clinical services. *JAMA*. 2012;308(19):2012-2019. doi:10.1001/jama.2012.14126.
30. López L, Grant RW. Closing the gap: eliminating health care disparities among Latinos with diabetes using health information technology tools and patient navigators. *J Diabetes Sci Technol*. 2012;6(1):169-176.
31. Lyles CR, Harris LT, Jordan L, et al. Patient race/ethnicity and shared medical record use among diabetes patients. *Med Care*. 2012;50(5):434-440. doi:10.1097/MLR.0b013e318249d81b.
32. http://clinicaltrials.gov/show/NCT01427660. Accessed November 10, 2014.
33. Zhang Y, He D, Sang Y. Facebook as a platform for health information and communication: a case study of a diabetes group. *J Med Syst*. 2013;37(3):9942. doi:10.1007/s10916-013-9942-7.
34. Sinsky CA, Beasley JW, Simmons GE, Baron RJ. Electronic health records: design, implementation, and policy for higher-value primary care. *Ann Intern Med*. 2014;160(10):727-728. doi:10.7326/M13-2589.
35. Campbell EM, Sittig DF, Ash JS, Guappone KP, Dykstra RH. Types of unintended consequences related to computerized provider order entry. *J Am Med Inform Assoc*. 2006;13(5):547-556.
36. Lyles CR, Sarkar U, Osborn CY. Getting a technology-based diabetes intervention ready for prime time: a review of usability testing studies. *Curr Diab Rep*. 2014;14(10):534. doi:10.1007/s11892-014-0534-9.