Using Health Information Technology to Improve Hypertension Management

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High-quality medical care requires implementing evidence-based best practices, with continued monitoring to improve performance. Implementation science is beginning to identify approaches to developing, implementing, and evaluating quality improvement strategies across health care systems that lead to good outcomes for patients. Health information technology has much to contribute to quality improvement for hypertension, particularly as part of multidimensional strategies for improved care. Clinical reminders closely aligned with organizational commitment to quality improvement may be one component of a successful strategy for improving blood pressure control. The ATHENA-Hypertension (Assessment and Treatment of Hypertension: Evidence-based Automation) system is an example of more complex clinical decision support. It is feasible to implement and deploy innovative health information technologies for clinical decision support with features such as clinical data visualizations and evidence to support specific recommendations. Further study is needed to determine the optimal contexts for such systems and their impact on patient outcomes.

Introduction

Substantial improvement gaps separate our actual achievements in medical practice from the best practices proven in clinical trials. Hypertension is a well-known cardiovascular risk factor; adequate blood pressure (BP) control can significantly decrease morbidity. Despite an excellent evidence base to define best practices, and widely disseminated national guidelines for hypertension management, achieved practice falls far short of optimal. Such improvement gaps appear in many areas of medicine, and the US Institute of Medicine (IOM) has identified them as targets for quality improvement [1]. In the United States, hypertension is underdiagnosed and undertreated [2]. The IOM has identified hypertension as one of the top clinical priorities for quality improvement in US health care. As described eloquently by Harvard University surgeon Atul Gawande, MD, in his recent book *Better*, high-quality medical care depends heavily on performance improvement through careful attention to the application of established procedures [3].

A new discipline, known as "implementation science" addresses the science of investigating what does and does not work for quality improvement. It proceeds through steps of developing, implementing, and evaluating potential quality improvement strategies. Implementation science can be conducted at many different levels of health care, ranging from an individual physician's practice, through medical centers and health care systems, and even at the national health policy level; applications in international health have also been described [4•]. Quality improvement strategies for hypertension management have been carefully studied in a large number of clinical trials. The Agency for Healthcare Quality Research (AHRQ) has funded systematic literature reviews of quality improvement strategies for several top clinical priority areas identified by the IOM, including hypertension [5]. My colleagues and I, who conducted the systematic review of hypertension for the AHRQ study, found that quality improvement strategies for hypertension are associated with improved hypertension control. We found that team change—in which a health professional other than the primary care provider assumed some responsibility for managing hypertension—was associated with substantial improvement [6•].

In its landmark book *Crossing the Quality Chasm*, the IOM also noted that health information technology has the potential to improve quality but has been underutilized in health care settings [1]. Health information technologies, new and old, can support improved clinical care in many ways: databases and registries for easy identification of patients to target with interventions; streamlined access to medical literature; readily available calculators for cardiac risk, estimated glomerular filtration rate, and other computations; software for analyzing ambulatory BP monitor readings; personalized health records for patients to monitor their own disease management; and many others. A review of all such technologies as they pertain to hypertension is well beyond the scope of this paper. There has recently been major growth in the use of electronic health records (EHRs). EHRs, if well designed and implemented, can provide tools for recording and measuring health data to support quality improvement projects, and can serve as a platform for delivering clinical decision support to assist health professionals in implementing best practices. This paper focuses on point-of-care clinical decision support enabled by the EHR, drawing on selected examples from a large literature without attempting a comprehensive review.

Physician Self-Awareness of Adherence to Clinical Practice Guidelines

Substantial epidemiologic evidence exists that physicians are treating common chronic diseases inadequately, a phenomenon sometimes attributed to clinical inertia [7]. A study at five Veterans Health Administration (VHA) medical centers in New England in the 1990s reported very low rates of intensification of therapy for substantially elevated BPs, with repeated delays by the physician in changing the medication regimen [8]. In the years since these reports were published, substantial work has offered insight into reasons that managing physicians did not intensify therapy. In many cases, clinicians may be making appropriate judgments about the risk-benefit ratios of adding additional antihypertensive medications. For example, in a recent analysis of clinical data for treated hypertensive patients, we found potential risks in aggressive management of those with chronic kidney disease [9•].

Physicians may believe they are adhering to guidelines when in reality they are not. In a study comparing primary care providers' self-reports of their adherence to guidelines with their actual patient care recorded in an electronic record, we found that primary care providers at three large medical centers were not aware of their own nonadherence to the guidelines [10]. This finding is consistent with studies of self-assessment among medical professionals in other clinical areas, which have also demonstrated substantial gaps between perceptions and behavior. Rose et al. [11], using a different methodology and different medical centers, found a discrepancy between clinicians' assertion that the patient's BP was well controlled and the objective evidence. Clinician profiling in which clinicians are provided with reports on their own performance may be effective as part of a multidimensional strategy; profiling may be particularly effective as a "priming" strategy that may make clinicians more receptive to subsequent interventions (eg, reminders and other real-time clinical decision support) [10].

Clinical Reminders

Several large health care systems now use health information technology to improve clinical care. The VHA of the US Department of Veterans Affairs was an early leader in health informatics and in adoption of performance measurement for practice improvement [12]. VHA has had automated information systems with extensive capabilities since 1985. The Veterans Health Information Systems and Technology Architecture (VistA) supports the computerized patient record system (CPRS) released in 1997. CPRS serves as an EHR and supports additional capabilities, including a clinical reminder system for real-time decision support [12]. VHA, which is the largest integrated health care system in the country, has outperformed the best-performing health care systems reporting comparable measures for hypertension [12].

Clinical reminders link guideline recommendations to a specific patient and so provide patient-specific clinical decision support. In a study of 49 VHA clinics with 451 primary care providers, the adherence rate across 15 clinical reminders was high at 83%; however, this study did not include hypertension reminders [13]. Clinical reminders are activated at the option of the local VHA medical center; most choose to activate reminders that are closely linked to clinical performance measures. Complete information about adoption of clinical reminders is not available; however, survey data provide a good estimate. Staff from 104 VA medical centers, of a total of 142 medical centers participating in the VA External Peer Review Process, responded to a survey about clinical reminders; 91 of these medical centers had implemented a hypertension reminder at the time of the survey [14].

In addition to clinical reminder functionality designed into an EHR, other reminder contexts have been employed to good effect. Heidenreich et al. [15,16•] have shown that clinical reminders attached to echocardiography reports by the cardiologist reading the report were effective in increasing prescribed doses of angiotensin-converting enzyme inhibitors and in increasing the use of β-blockers for patients with depressed left ventricular systolic function.

What do we know about the effectiveness of clinical reminders regarding hypertension management? More than 25 years ago, Barnett et al. [17] at the Massachusetts General Hospital deployed an automated surveillance system with the computer-based medical record system Computer-Stored Ambulatory Record (COSTAR) to improve follow-up of patients with newly identified elevated diastolic BP. In a randomized clinical trial, follow-up was significantly improved in the group with computer-generated reminders. Many subsequent studies have shown the effectiveness of clinical reminders for a variety of medical scenarios; however, achieving improvements in clinical care with reminders may be easier for preventive care and drug monitoring than for chronic diseases [18]. Findings in some earlier studies of reminders for hypertension were disappointing. A 2002 review of physician educational interventions focusing on hypertension reported that the interventions, especially reminders, improved the follow-up of hypertension but were ineffective in changing BP levels [19].

Investigators at the Indiana University School of Medicine, who have developed several successful automated systems providing recommendations for physicians in other clinical domains, studied a system for computerized hypertension treatment suggestions in a randomized clinical trial with physician, pharmacist, and dual-intervention arms compared with control. Recommendations for treatment were displayed to physicians as "suggested orders" on computer workstations. No statistically significant effects were seen on either adherence to the medication prescribing recommendations or on patients' BPs [20]. The authors noted many potential explanations for the negative finding, including possibly that it was too easy for physicians to use the computer "escape" key to bypass the recommendation.

In a different study, involving 275 resident physicians at 12 VHA medical centers, randomly allocated residents were presented with clinical reminders for 13 standards of care on paper and by computer at the time of clinic visits. The investigators found that the reminder group had higher rates of compliance overall than the control group; however, there was no difference between study arms for the hypertension standard of care [21]. This study was conducted early in the VHA's process of organizational change to improve hypertension management, and the hypertension reminder used in the study did not focus on target BP.

As an early step in the ATHENA (Assessment and Treatment of Hypertension: Evidence-based Automation) project, our group conducted a randomized clinical trial of a two-dimensional strategy in which we provided VA primary care providers with 1) quarterly profiling of their individual performance (as a priming strategy), and 2) hypertension reminders at each clinic visit for hypertensive patients. This study was conducted before the clinic sites had fully implemented the electronic record. Reminders of guideline-recommended medications were generated from the electronic pharmacy, diagnosis, and appointment data systems, and delivered to the clinicians on paper along with encounter forms and health summaries for clinic visits. The strategy resulted in improved prescribing, which was the primary outcome measure [22].

As experience is gained with designing and integrating clinical reminders and aligning them with organizational objectives, the impact may be even more positive. The current VHA hypertension reminder [23] focuses on BP control and is better integrated with clinical workflow, helping the clinician to complete necessary tasks such as entering data to the medical record. The current VHA hypertension reminder may also be used to generate "reminder reports" that provide rapid clinician profiling to summarize performance. In a recent news report about a paper at the American Heart Association meeting, Dr. Ross Fletcher credited the hypertension clinical reminder with a substantial role in achieving the well-recognized high rates of BP control in VHA [24].

Powerful as clinical reminders are, they also have significant limitations. As discussed in more detail later, clinical reminder functionality in most EHRs is based on a rule system that does not lend itself to complexities of medical knowledge. Accordingly, clinical reminders generally do not take account of many of the patient's clinical characteristics, limiting their acceptability to clinicians. Clinicians interviewed about barriers to using reminders reported the reminders were too basic or not relevant to particular patients [25]. Human factors barriers to using an HIV clinical reminder have been studied in detailed ethnographic field observations in clinic settings and in semistructured interviews [26]. Inapplicability of the clinical reminder due to patient situation specifics was one of six factors accounting for failure to use the clinical reminder. These findings suggest the need for forms of clinical decision support that can take account of more of the patient's clinical characteristics. For an automated system to do this, it is necessary to model clinical knowledge in computer-interpretable formats in sufficient detail to process several different variables in patient data.

Field study of clinical reminder use in actual practice settings has also identified integration of reminders into workflow and incorporation of a feedback mechanism as facilitators for use [27]. In light of the limitations of clinical reminders because of inapplicability to specific patient situations, newer forms of clinical decision support have been developed that use more extensive clinical knowledge and can thereby take account of more of a patient's clinical characteristics than typical reminders. Some of these systems also address workflow issues by incorporating write-back capabilities to obviate the need for double-entry of information to the medical record, and also provide feedback mechanisms for clinicians to notify developers of problems.

Innovative Clinical Decision Support

Because of its high prevalence and important morbidity, together with the existence of efficacious treatments and widely disseminated clinical practice guidelines, hypertension has been a common target for computer-based decision support. In addition to the early system developed for COSTAR and the system used in the Indianapolis study (both described previously), several others have been developed [28–36]. Although much was learned from the development of these systems, few are still in use. With advances in computing technology, newer approaches to decision support have been developed, as described below.

Developers of clinical reminders typically encode the clinical knowledge in situation-action rules. A rule-interpreter function processes the rules by determining when a situation exists, based on the patient data, that triggers the rule (eg, that a patient has hypertension) and then evaluating whether the condition part of the rule pertains (eg, if the BP is above target). Situation-action rules can be hard to maintain: there may be unanticipated interactions among rules. It may also be difficult to include substantial clinical knowledge and to represent overall plans such as those provided in guidelines. [37]. Because of these and other limitations of rule-based systems, medical informaticians have developed different architectures for more elaborate automated application of clinical knowledge, particularly clinical practice guidelines. A successful approach to representing clinical knowledge in computer-interpretable formats is the EON architecture developed at Stanford University [38]. The following sections describe a hypertension decision support system known as ATHENA-Hypertension, built with the EON architecture.

ATHENA-Hypertension decision support system

The ATHENA-Hypertension (HTN) decision support system was developed as part of the ATHENA project to explore developing, implementing, and evaluating approaches to improve hypertension management. ATHENA-HTN includes a knowledge base that models hypertension knowledge in computer-interpretable formats, and a guideline interpreter, also known as an execution engine, that processes patient data to generate patient-specific recommendations consistent with the data in the knowledge base. The knowledge base was created and is maintained with Protégé, a widely used open-source knowledge acquisition software developed at Stanford University [39]. The system is designed to be integrated with an electronic medical record [40]. Clinical data used by the system include diagnoses, medications, BPs, selected laboratory values, and history of adverse drug reactions. The system includes features that provide explanations of the recommendations to the clinicians, and links to resources that highlight the evidence supporting a specific drug recommendation in a specific clinical scenario [41]. Design of the system included planning to identify and address anticipated potential problems that could affect patient safety, because new information technology can introduce new sources of error [42].

ATHENA-HTN was integrated with the VHA VistA to generate advisory displays to primary care providers. These advisories appear within the window of the CPRS when an eligible primary care clinician selects the record of an eligible patient at a point in time appropriate for managing chronic hypertension (ie, in proximity to a scheduled primary care clinic visit). The advisory display shows the patient's BP target (depending on the patient's comorbidities) and whether or not the patient's most recent BP meets the target. The top screen of the display provides a primary recommendation related to BP control; lists currently prescribed but unfilled antihypertensive medications, if any, as a potential alert to discuss adherence with the patient; and provides a table of drug recommendations linked to the patient's comorbidities. Tabs are available to show screens with additional information. A BP prescription tab displays the patient's antihypertensive medications graphically on the same timeline as BPs so that response to medications can be viewed rapidly [43••].

Many promising health information systems have encountered substantial difficulties in implementation and deployment. We recognized that developing the system was only the first step, and that interrelationships of the technical design with the clinical and organizational context would play a major role in successful deployment of the system; accordingly, we worked closely with the major stakeholders [44]. The system was deployed in 2002 in three large VA medical centers and studied at all three over a 15-month period. We found that primary care clinicians interacted with the system extensively, suggesting the usefulness and usability of the system [44].

The knowledge base for ATHENA-HTN has been updated to conform to more recent guidelines. The current system is being evaluated as part of a multifactorial behavioral/educational and medication management intervention at Durham VA Medical Center. In this study, nurses monitor home BPs sent automatically via telephone to a secure server. In the medication management study arms, nurses use ATHENA-HTN to prepare suggested medication orders for physician review. This study's approach of giving a health professional other than the primary care provider—in this case, a nurse—some responsibility for managing hypertension is consistent with the previously described findings of the systematic review of effective quality improvement strategies [6•]. The system is also being deployed in five VA medical centers in New England as part of a study that we hope will provide insights into organizational issues of implementing new health information technology. Further system developments for the new deployment have included programming to allow for use in "thin client" CPRS environments and write-back capability for BPs entered by the clinician into the ATHENA-HTN interface to obviate the need for double-entry of additional BP measurements during the clinic visit.

Patient safety in health information technology

Health information technology is often promoted as a solution to patient safety problems, and new information technologies have much to contribute in that regard [45]. Nevertheless, it is important to recognize that new technologies can introduce new sources of error. For example, an observational case study of the introduction of computerized physician order-entry to an intensive care unit found that it required new workflows, which introduced new areas for potential errors [46]. As noted earlier, it is important to design a decision support system with patient safety in mind, considering potential new opportunities for error early in development and designing to minimize them [42]. Testing the system's performance accuracy before deployment and after updates is essential. Methods for monitoring to maintain accuracy should be incorporated into the system to further enhance patient safety once the system is in use [47•,48].

How a Clinical Decision Support System Can Contribute to Understanding Barriers to Clinician Guideline Adherence

Cabana et al. [49] described a framework for conceptualizing the reasons physicians do not adhere to guidelines. ATHENA-HTN includes two methods for clinician-users to provide feedback to the developers: a checklist of reasons for not adhering to displayed drug recommendations and a box for entering free-text comments that could address any topic. Many of the comments entered by clinicians provided reasons why they were not adopting the recommendations. We applied the Cabana et al. [49] framework to guide analysis of these comments [50•]. The information about not following the guideline recommendations, presented at the time of medical decision making and linked to specific patients, is a rich source for insight into reasons that clinicians elected not to follow guideline recommendations. We found that many clinicians identified patient nonadherence to medication as the reason for not intensifying antihypertensive drug therapy, which may be a clinically appropriate decision, particularly if the clinic visit time is used to encourage patient adherence. Clinicians identified several other patient factors as reasons for not intensifying therapy when faced with an elevated BP, including a belief that the recorded office BP was not representative of the patient's typical BP. Information of this sort about barriers to clinician guideline adherence can be used to develop new strategies for improving an organization's management of hypertension.

Conclusions

High-quality medical care requires implementing evidence-based best practices and continued monitoring to improve performance. Implementation science is beginning to identify approaches to developing, implementing, and evaluating quality improvement strategies across health care systems that lead to good outcomes for patients. Health information technology has much to contribute to quality improvement for hypertension, particularly as part of multidimensional strategies for improved care. Clinical reminders closely aligned with organizational commitment to quality improvement have likely played a major role in improving BP control in the VHA. It is feasible to implement and deploy innovative health information technologies for clinical decision support with attractive features such as displaying visualizations that summarize complex clinical data succinctly; taking account of more of a patient's clinical characteristics than clinical reminders do; and providing evidence to support specific recommendations. However, further study is needed to determine the optimal formats for such systems and their ultimate impact on clinical practice and patient outcomes.

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Disclosure

No potential conflict of interest relevant to this article was reported.

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