Impact of Home Blood Pressure Data Visualization on Hypertension Medical Decision Making in Primary Care

Deborah J. Cohen, PhD[1]
Tamar Wyte-Lake, DPT[1]
Shannon M. Canfield, PhD, MPH[2]
Jennifer D. Hall, MPH[1]
Linsey Steege, PhD[3]
Nuha K. Wareg, MPH[2]
Richelle J. Koopman, MD, MS[2]

[1]Department of Family Medicine, Oregon Health and Science University, Portland, Oregon

[2]Department of Family & Community Medicine, University of Missouri-Columbia, Columbia, Missouri

[3]School of Nursing, University of Wisconsin-Madison, Madison, Wisconsin

Conflicts of interest: authors report none.

CORRESPONDING AUTHOR

Deborah J. Cohen
Oregon Health & Science University
Department of Family Medicine
3181 SW Sam Jackson Park Rd
Portland, OR 97213
cohendj@ohsu.edu

ABSTRACT

PURPOSE Evidence shows the value of home blood pressure (BP) monitoring in hypertension management. Questions exist about how to effectively incorporate these readings into BP follow-up visits. We developed and implemented a tool that combines clinical and home BP readings into an electronic health record (EHR)-integrated visualization tool. We examined how this tool was used during primary care visits and its effect on physician-patient communication and decision making about hypertension management, comparing it with home BP readings on paper.

METHODS We video recorded the hypertension follow-up visits of 73 patients with 15 primary care physicians between July 2018 and April 2019. During visits, physicians reviewed home BP readings with patients, either directly from paper or as entered into the EHR visualization tool. We used conversation analysis to analyze the recordings.

RESULTS Home BP readings were viewed on paper for 26 patients and in the visualization tool for 47 patients. Access to home BP readings during hypertension management visits, regardless of viewing mode, positioned the physician and patient to assess BP management and make decisions about treatment modification, if needed. Length of BP discussion with the visualization tool was similar to or shorter than that with paper. Advantages of the visualization tool included ease of use, and enhanced and faster sense making and decision making. Successful use of the tool required patients' ability to obtain their BP readings and enter them into the EHR via a portal, and an examination room configuration that allowed for screen sharing.

CONCLUSIONS Reviewing home BP readings using a visualization tool is feasible and enhances sense making and patient engagement in decision making. Practices and their patients need appropriate infrastructure to realize these benefits.

Ann Fam Med 2022;20:305-311. https://doi.org/10.1370/afm.2820

INTRODUCTION

Hypertension is a serious, prevalent disease affecting more than 100 million American adults.[1] High blood pressure (BP) contributes 40.6% of the attributable risk for heart and cardiovascular disease mortality, more than double that from smoking, poor diet, inactivity, or diabetes.[2] Yet only 24% to 54% of Americans with diagnosed hypertension have controlled BP.[3,4] Clinical uncertainty about how a single measured BP represents overall hypertension control contributes to high rates of uncontrolled hypertension,[5,6] and, in the case of a possible white coat effect, risk of causing hypotension.[7-10] This uncertainty leads to postponing medication intensification to gather more data, contributing to the phenomenon of clinical inertia.[5,11] Patient uncertainty also influences decisions about control, as patients try to reconcile systolic BPs that can vary by up to 60 mm Hg in a day.[12,13]

Home BP data may help improve decisional certainty.[6] Evidence suggests that home BP predicts cardiovascular outcomes even after accounting for in-clinic BPs, prompting the US Preventive Services Task Force and professional societies to promote in their guidelines the inclusion of home data for hypertension diagnosis and management.[1,14-16] Fifty-four percent of US adults with diagnosed hypertension report measuring their BP at home. Home BP data recorded in paper lists, spreadsheets, or mobile applications, however, fit poorly with physicians' increasingly electronic health record (EHR)-based workflow, creating obstacles to incorporating these data into decision making. In fact, less than 30% of patients who measure BP at home share these data with their physician.[17,18]

To overcome this obstacle, we created and implemented an EHR-based visualization tool with input from patient and clinician users. This tool's development and function have been described elsewhere.[13,19-21] Briefly, patients manually populate the EHR, via a portal, with home BP readings. These values are incorporated with in-clinic BP readings and a corresponding medication timeline. Although the patient is unable to see the graph via the portal, the patient and physician can view the data graphically together in the clinic.

For this study, we observed primary care hypertension follow-up visits before and after implementation of the EHR-based visualization tool to determine (1) ways in which patient-supplied home BP data were used in hypertension management decisions, (2) differences in patient-physician interactions when home BP readings were provided on paper vs in the visualization tool, and (3) logistic factors requiring consideration to optimize use of the visualization tool.

METHODS

Sample

This study was conducted in 3 academic, community-based primary care practices in the midwestern United States that are part of a 10-practice network serving more than 60,000 patients across 4 counties, with a mix of suburban and rural settings. Practices in this system used the same EHR system. Recruitment was conducted from July 2018 to April 2019. The University of Missouri Institutional Review Board approved this study protocol.

We approached 18 primary care physicians about the study via a presentation at a faculty meeting, followed by an e-mail invitation; 15 agreed to participate. Physician participants were asked to review registry-generated lists of patients with hypertension to exclude from the study those having factors that would affect participation (eg, cognitive impairment, mental illness, or acute illness). Patients did not have to own a BP monitor to participate, as they could use public devices such as those found at pharmacies. We sent a letter describing the study and consent information to 430 eligible patients and recruited 89 of those who had a scheduled hypertension follow-up visit.

Data Collection

The study spanned periods before and after implementation of the EHR-based visualization tool. Each physician participated in up to 6 video-recorded sessions, including up to 2 visits with home BP readings recorded on paper and up to 4 visits with home BP readings displayed via the EHR visualization tool. This design ensured that performance bias, if present, would be equal across paper and visualization tool conditions. One physician left the practice before concluding his final visualization tool visit and was excluded. Sixteen additional visits were excluded because of technical difficulties (eg, videotaping problems, BP not discussed during the visit).

Previsit Preparations

We visited practices to test equipment, inform staff about the study, and establish a protocol to minimize clinic disruptions. All patients were sent an e-mail in advance with instructions on taking a home BP reading; those recruited before implementation of the visualization tool were sent instructions for documenting readings on paper, whereas those recruited after implementation of the tool were sent instructions on how to enter their home BP readings using the patient portal. All patients were also sent a photo of study staff to aid recognition at the visit.

Patients were asked to meet study staff 15 minutes before their visit and to supply 30 days of home BP readings, either in written form for the paper group, or uploaded through the patient portal for the visualization tool group. Patients in the latter group who had not uploaded their readings at home received additional, in-person instruction by study staff. Those still unable to use the portal conveyed their data verbally (5 patients) or by secure e-mail (4 patients) to study staff who entered the data into the EHR before the visit with the physician.

Visit Recording

Study staff obtained written consent to video record from physicians and Health Insurance Portability and Accountability Act (HIPAA) authorization/consent from patients. We connected a HIPAA-compliant study laptop, equipped with Morae version 3.3.4 recording software (Techsmith Corporation), into the EHR, and mounted a video camera on a tripod positioned to record physician and patient body behavior. This setup allowed us to record audio and video of the patient and physician interaction, and concurrent video of the computer screen, including EHR navigation. If a physical examination was performed during the visit, study staff entered the room and turned the video off before that part of the visit to respect patient privacy.

Data Management and Analysis

Audio recordings were professionally transcribed and deidentified. Transcripts, video recordings, video-recording notes, and written home BP materials collected by the research team were entered into ATLAS.ti version 8 (Scientific Software Development GmbH).[22]

We used a conversation analytic approach[23-26] to understand the BP discussion, with an emphasis on understanding physician and patient actions, and the implications for decision making. To start, we analyzed several recorded visits with the full research team, which included qualitative analysts, developers, physicians, and data collectors. We watched the video recordings and tagged and discussed segments related to BP management. We developed a shared understanding of these segments, giving a preliminary name to the actions and sequences of actions observed, and noting similarities and differences between discussions that used paper and the visualization tool. Next, a smaller team (T.W-L.,

J.D.H., D.J.C.) used what we learned from the larger group to analyze the remaining data. We observed that the BP management discussions consistently followed a series of steps for all physicians. We analyzed data across physicians, comparing how the different modes of viewing the BP data shaped each step in the interaction. This process included analyzing how room layout and patient and physician positioning influenced the interaction. We analyzed visits with patients who had controlled blood pressure, as defined by the physician during the visit (eg, telling patients their BP was in normal range), and compared these with visits by patients with uncontrolled hypertension to discern differences. We met with the larger team at regular intervals to review emerging findings.

We evaluated visit length by subtracting time at visit start (physician entering the examination room) from time at visit end (patient leaving the examination room). We calculated length of the BP conversation by subtracting time at BP topic initiation from the time at topic closure and/or end of visit. For visits in which BP conversations occurred in more than 1 discrete segment with intervening discussion of other concerns, we summed the times for BP discussion, excluding off-topic discussions. To analyze these data, we separated visits according to whether a medication change was discussed; we hypothesized that visits without this discussion might be shorter, but not because of the data display modality. We reviewed descriptive data, drawing comparisons among different visits types, as sample sizes were too small to conduct multivariate analyses.

RESULTS

Characteristics of the 15 physicians and the 73 patients whose hypertension follow-up visits were video recorded are shown in Table 1. Home BP readings were viewed on paper for 26 patients and using the EHR visualization tool for 47 patients, with all physicians having at least 1 visit using each viewing mode. In the cohort overall, 57 patients had controlled hypertension and 16 patients had uncontrolled hypertension.

BP Discussions

Access to home BP readings during the hypertension follow-up visits, regardless of how they were viewed, positioned the physician and patient to engage in a discussion in which they assessed the patient's BP management, determined whether the patient's BP was controlled, and made decisions about modifying the hypertension treatment plan. Discussion of home BP consistently occurred in the following steps: (1) initiation of the BP topic, (2) acknowledgment of receipt of home BP values, (3) review of trends in the BP readings, (4) discussion of the assessment of these readings, and (5) discussion of hypertension management, with a treatment decision being reached. Supplemental Appendix 1 shows an example of a typical BP discussion.

Paper Visits vs Visualization Tool Visits

We observed differences in BP management discussions during visits wherein home BP readings were viewed on paper vs in the visualization tool. We highlight 3 aspects of the interaction below and give examples from the recordings. We also note similarities and differences between viewing methods.

Topic Initiation and Clinician Receipt of Home Data

When home BP measurements were viewed on paper, both patients and physicians could initiate the discussion (Supplemental Appendix 2). In contrast, during visits using the visualization tool, physicians checked to see whether home BP data were available in the EHR before the visit. Although physicians knew whether these readings were in the EHR, patients were not sure of this. We observed patients asking physicians whether they saw the BP readings, physicians directing patients to the monitor to see the data, or both. Either action initiated the topic of BP management (Supplemental Appendix 3, lines 1-6).

Table 1. Patient and Physician Characteristics

Characteristic	Patients (N = 73)		Physicians (N = 15)
	Paper (n = 26)	Visualization Tool (n = 47)	
Sex, % (No.)			
Female	57.6 (15)	55.3 (26)	60.0 (9)
Male	42.3 (11)	44.6 (21)	40.0 (6)
Age, mean, y	64.0	64.0	44.6
Age >60 years, % (No.)	57.6 (15)	68.0 (32)	n/a
Race, % (No.)			
White	92.3 (24)	85.0 (40)	80.0 (12)
Black/African American	7.6 (2)	12.7 (6)	0 (0)
Alaskan/American Native	0 (0)	2.1 (1)	0 (0)
Missing	n/a	n/a	13.3 (2)
Multiple	0 (0)	0 (0)	6.7 (1)
Education, % (No.)			n/a
Some college or greater	76.9 (20)	74.4 (35)	
High school or GED	19.2 (5)	17.0 (8)	
Some high school	3.8 (1)	8.5 (4)	
Time in practice, % (No.)	n/a	n/a	
≤5 years			20.0 (3)
6-20 years			53.3 (8)
21-30 years			26.6 (4)
Time in practice with UMHC, % (No.)	n/a	n/a	
≤5 years			13.3 (2)
6-20 years			73.3 (11)
21-30 years			13.3 (2)

GED = general equivalency diploma; n/a = not applicable; UMHC = University of Missouri Health Care.

Reviewing Trends and Negotiating an Assessment of BP Management

Regardless of how the BP readings were viewed (on paper or in the visualization tool), physicians and patients reviewed the home BP trends over time, comparing them against in-clinic BP readings. They did this in a manner that displayed and negotiated their assessment of BP management, which focused on the extent to which the BP was adequately controlled.

The process of reviewing and negotiating varied between paper and visualization tool visits. For example, when reviewing these numbers on paper (Supplemental Appendix 2), physicians sometimes read them aloud and offered an assessment (eg, "So all of these so far look good"), with patients responding by agreeing or disagreeing. To make a comparison with in-clinic readings, physician needed to navigate to those data in the EHR.

The process of reviewing the trend in BP readings differed when using the visualization tool (Supplemental Appendix 3). Physicians, after navigating to the visualization tool in the EHR, oriented patients to what they were seeing on the graph, explaining what the colors meant, and using the mouse or their finger to point to the range and other graph features. After this orientation, the physician and patient jointly reviewed trends, typically without reading numbers aloud. The example illustrates how the physician used the graph to share her observation that most of the BP readings were in the normal range (lines 9-15) and then offered a positive assessment "most of it's been looking pretty good" (line 15) and the patient agreed (line 16).

Although not discussed or shown in Supplemental Appendix 3, in-clinic and home BP readings were displayed on the same graph, making additional EHR navigation to find clinic BP readings unnecessary. Supplemental Appendix 4 shows the visualization tool display with BP medications—denoted by gray bars located below the graph—and indicating when past and current medications started and stopped. Physicians used this feature to prompt questions about possible adverse effects of medication when BP was running low, to adjust medication when BP was too high, and to reinforce the positive impact of medication by highlighting the alignment between medication initiation and a reduction in BP (Supplemental Appendix 4, lines 4-8). In contrast, there was no point of comparison with BPs recorded on paper; in these visits, physicians discussed medications, recalling and reviewing the medication list in the EHR to identify when medications were stopped and started, if needed.

Assessing Hypertension Control and Refining the Treatment Plan

Diagnosis and treatment, including a plan of no treatment change, were conducted in the same way when paper and the EHR visualization tool were used. Supplemental Appendix 3 shows an example of the latter. A positive (no problem) assessment of BP control led to an assessment that the patient's hypertension was well controlled. This assessment was also made when in-clinic BP readings were elevated, but home BP readings were not (ie, white coat syndrome). Agreement that no treatment adjustments were needed often closed the topic of BP. Supplemental Appendix 2 shows an example of a visit in which BP readings on paper were used.

Visit Efficiency

The visualization tool did not make a large difference in visit efficiency (Table 2). For the 57 patients with controlled hypertension, use of the EHR visualization tool shortened the mean time needed to discuss BP: from 6.5 minutes to 3.1 minutes when a medication change was discussed, and from 3.9 to 3.2 minutes when it was not. For the 16 patients with uncontrolled hypertension, all of whom had a discussion of medication change, the time taken to discuss BP was similar,

Table 2. Comparison of BP Discussion Time and Visit Time Using Paper vs Visualization Tool

	Controlled Hypertension (n = 57)		Uncontrolled Hypertension (n = 16)	
Discussion and Measures	Paper (n = 23)	Visualization Tool (n = 34)	Paper (n = 3)	Visualization Tool (n = 13)
Medication change discussed				
Number of patients	6	6	3	13
Length of BP discussion, mean (range), min	6.5 (3-11)	3.1 (2-12)	6.2 (4-9)	6.8 (2-16)
Length of visit, mean (range), min	16.5 (13-27)	18.0 (12-22)	26.2 (15-39)	18.8 (4-29)
Medication change not discussed				
Number of patients	17	28	0	0
Length of BP discussion, mean (range), min	3.9 (1-8)	3.2 (2-5)	...	...
Length of visit, mean (range), min	17.5 (6-29)	17.3 (6-28)	...	...

BP = blood pressure.

on average, whether paper or the visualization tool was used, at 6.2 minutes and 6.8 minutes, respectively.

Logistics for Using the Visualization Tool

Using the EHR visualization tool required patients to input home BP readings before the visit. Some patients were unable to do so. When these data were not entered in advance, the physician and patient deferred to paper or to the patient's memory. In addition, the examination room layout, ergonomics, and usability features (ie, location and mobility of the computer screen, location of chairs, size of text, graphical displays on the screen) were important for effectively using the visualization tool with patients. Ideally, the physician and patient would sit within 1 to 3 feet of each other, close to the computer monitor that was attached to the wall with a flexible arm. This configuration made screen sharing easier, allowing both parties to see the visualization tool.

DISCUSSION

We observed that home BP readings, whether presented on paper or in an EHR visualization tool, can inform hypertension management follow-up visits. The visualization tool we developed displayed in-clinic and home BP readings alongside a medication timeline, which created an additional opportunity for physician and patient understanding about the relationship between medication changes and BP control. As uncertainty about BP control is an important factor in hypertension therapeutic inertia, this type of visualization may help joint decision making about BP management, as well as improve BP control,[5] without adding additional visit time.

Improved technology tools alone rarely transform medical decision making, as all decision support is part of a larger sociotechnical system.[27] The required tasks, physical environment, organizational context, and users themselves are all important components that influence patient and physician collaboration and outcomes of care, and warrant attention.[28] This study illustrates the impact the physical environment had on use of an EHR visualization tool to facilitate shared communication and decision making. Improving these components can lead to higher-quality and safer care; conversely, not attending to them can lead to a predictable lack of use of the tools, as well as oversights and failures in care.

The patient effort required to collect home BP readings and bring them to the appointment is foundational to integrating these important data into clinical decision making. There is increasing attention within human factors models on understanding and supporting patients as active participants in their health and care.[28-30] Additional work is needed to improve home BP data entry tools to support patient independence in this process; in particular, more development is needed to provide patients with cues and feedback to confirm that they have successfully completed the task. Additionally, trying to better incorporate these data in clinical decision making honors the patient effort required to collect and share these data. As such, bringing home BP into the electronic workflow of the hypertension visit is a priority. Patient observation of physicians actively using their carefully collected home BP data may be an important motivator to continue to collect these data when needed.

Health care policy change can catalyze the evidence-based use of home BP readings in clinical practice. Medicare has begun to support 2 crucial elements of the work of primary care teams with regard to home BP review with new Current Procedural Terminology codes and reimbursement (1) for patient education on proper home monitoring technique and (2) for the work physicians and other qualified professionals do in reviewing, summarizing, and making decisions based on home BP data, either during or between visits, in person or remotely.[31] Furthermore, in 2019, the National Committee for Quality Assurance added home BP data, if electronically submitted directly to the clinician, as data that could satisfy the High Blood Pressure Healthcare Effectiveness Data and Information Set (HEDIS) measure. This policy links the evidence-based use of home BP data to potential Medicare quality incentives[32] and will shape the implementation plans for health systems.

As use of home BP data becomes more prevalent, accumulating evidence may prompt reevaluation of the assumed superiority of ambulatory BP monitoring over home BP monitoring in terms of predicting cardiovascular events, accessibility, tolerability, and reimbursement.[33-36] To accomplish home BP monitoring on a large scale, patients will need to have a home BP monitor. Patient reimbursement for this purchase is excluded from Medicare Part B, is covered by very few commercial insurances, and has varying coverage by states in Medicaid expansion plans.[33] This situation contrasts with the widespread coverage for home glucose-monitoring devices, and likely requires reconsideration and revision to better align coverage with the changing policy environment.

Limitations

This study has some important limitations. First, it was conducted among a small sample of clinics based in an academic setting that used the same EHR system, and among a small sample of patients. Larger studies with more diverse samples are critical to understanding whether incorporating home BP readings into EHR workflow improves patient outcomes. Such studies can also help us understand how to educate and motivate patients to provide high-quality home BP data; what further decision support and information systems are needed for clinical care teams to manage these data; and the effect of collecting, interpreting, and using these data on the work of patients, nurses, and physicians. Second, although having a BP monitoring device at home was not required for study participation, factors influencing access to such devices should be considered by systems and researchers implementing home monitoring. Third, we did not examine the impact of patient literacy and the extent to which patients found the BP display in the visualization tool useful. These are rich areas for future research.

Conclusions

Integrating home and clinic BP readings and antihypertensive medications into the EHR and hypertension follow-up visit workflow is feasible. Reviewing this information using a visualization tool enhances sense making and patient involvement in BP management decisions, and does not take more time. Although further research is needed to examine the impact of reviewing home BP on outcomes, policy makers and practices can take important steps to ensure that patients and practice have the appropriate tools, payment, and infrastructure to realize these benefits.

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Key words: patient-generated health data; home blood pressure monitoring; hypertension control; clinical decision support; EHR; health information technology; ergonomics; data visualization; shared decision making

Submitted June 1, 2021; submitted, revised, November 30, 2021; accepted January 3, 2022.

Funding support: This project was supported by the Agency for Healthcare Research and Quality (grant number R01HS023328).

Disclaimer: The content of this article is solely the responsibility of the authors and does not necessarily represent the official views of the Agency for Healthcare Research and Quality.

Previous presentations: Implementation of a Home Blood Pressure Visualization Tool in the EHR: Early Experience, paper presented at the North American Primary Care Research Group Annual Meeting, November 2019, Toronto, Ontario, Canada. Implementation of a Home Blood Pressure Visualization Tool in the EHR: Early Experience, poster presented at the Society for Medical Decision-Making Annual Meeting, October 2019, Portland, Oregon. Impact of Blood Pressure Visualization Tool Use on Hypertension Medical Decision Making, paper presented at the North American Primary Care Research Group (NAPCRG) Annual Meeting, November 2020, Virtual Conference.

Supplemental materials

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