

A Technology-Based Quality Innovation to Identify Undiagnosed Hypertension Among Active Primary Care Patients

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ABSTRACT

PURPOSE The goal of this study was to develop a technology-based strategy to identify patients with undiagnosed hypertension in 23 primary care practices and integrate this innovation into a continuous quality improvement initiative in a large, integrated health system.

METHODS In phase 1, we reviewed electronic health records (EHRs) using algorithms designed to identify patients at risk for undiagnosed hypertension. We then invited each at-risk patient to complete an automated office blood pressure (AOBP) protocol. In phase 2, we instituted a quality improvement process that included regular physician feedback and office-based computer alerts to evaluate at-risk patients not screened in phase 1. Study patients were observed for 24 additional months to determine rates of diagnostic resolution.

RESULTS Of the 1,432 patients targeted for inclusion in the study, 475 completed the AOBP protocol during the 6 months of phase 1. Of the 1,033 at-risk patients who remained active during phase 2, 740 (72%) were classified by the end of the follow-up period: 361 had hypertension diagnosed, 290 had either white-coat hypertension, prehypertension, or elevated blood pressure diagnosed, and 89 had normal blood pressure. By the end of the follow-up period, 293 patients (28%) had not been classified and remained at risk for undiagnosed hypertension.

CONCLUSIONS Our technology-based innovation identified a large number of patients at risk for undiagnosed hypertension and successfully classified the majority, including many with hypertension. This innovation has been implemented as an ongoing quality improvement initiative in our medical group and continues to improve the accuracy of diagnosis of hypertension among primary care patients.

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INTRODUCTION

Hypertension affects 33% of all US adults aged 20 years and older¹; is the leading modifiable risk factor for coronary artery disease, stroke, congestive heart failure, and chronic kidney disease²; and is associated with billions of dollars of costs related to medical care and lost productivity.^{3,4} An estimated 18.5% of US adults with hypertension are unaware of their condition.¹ One in 14 US adults has a systolic blood pressure of ≥ 140 mm Hg or a diastolic blood pressure of ≥ 90 mm Hg but has never been told by a physician or health care professional that they have hypertension.⁵ Improved diagnosis and management of hypertension can reduce the clinical and financial burdens associated with this disease.^{3,6}

Most of those unaware of hypertension are regular users of health care.⁷ A recognized barrier to hypertension diagnosis is variability in office-based blood pressure measurements, which is associated with over- and underdiagnosis of hypertension.⁸⁻¹⁰ In contrast, ambulatory blood pressure monitoring more accurately reflects true blood pressure, is more strongly associated with cardiovascular morbidity and mortality,¹¹⁻¹⁴ and is recommended to

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confirm the diagnosis of hypertension.¹⁵ Ambulatory blood pressure monitoring is not well-tolerated by a substantial proportion of patients, however, and is uncommonly used in primary care practice.^{16,17} In recent years, automated office blood pressure (AOBP) devices have been used to record multiple measurements over a 5- to 10-minute period with the patient alone in the examination room. The mean of these blood pressure values has been shown to correlate well with daytime mean ambulatory blood pressure readings.^{18,19}

We describe the development and evaluation of a novel strategy to screen for undiagnosed hypertension and the implementation of a continuous quality improvement process based upon this strategy. Our primary research question was whether a process that combines computer-based algorithms with AOBP measurements and regular feedback to physicians can reduce the number of active primary care patients with undiagnosed hypertension.

METHODS

Patient Identification

Inclusion criteria for study patients were age of 18 to 79 years and being an active primary care patient, defined as having at least 1 visit documented in the electronic health record (EHR) with an assigned primary care physician (family physician or general internist) at one of 23 primary care practices within the 2 years before the beginning of the study on January 1, 2011. Those patients with *International Classification of Diseases, Ninth Revision (ICD-9)* diagnosis codes in their charts of 401.1-405.9 (primary or secondary hypertension) or 796.2 (white-coat hypertension, prehypertension, or elevated blood pressure) were excluded from the screening process. EHR charts without these codes were then searched using 3 computer-based screening algorithms designed to identify individuals with consistently elevated blood pressure readings and to exclude those with intermittently elevated blood pressure readings. Study algorithms were developed using established hypertension diagnosis guidelines,²⁰⁻²² and patients were considered at risk for undiagnosed hypertension if they met the criteria of any of the 3 algorithms. Inpatient, emergency department, and ambulatory surgery center blood pressure values were excluded to reduce the risk of including transiently elevated blood pressures from acute medical conditions.^{22,23}

Phase 1: Recruitment and Intervention

Initially, one author (M.K.R.) met with the lead physician from each of the 23 primary care practices to discuss the purpose and methods of the study and to review key journal articles regarding undiagnosed

hypertension.^{19,24,25} Lead physicians were asked to discuss the study with their practice colleagues and provide these articles upon request. After completion of the EHR query using the hypertension screening algorithms, each of the primary care physicians in these 23 practices received a list of their patients who met the criteria of any of the 3 hypertension screening algorithms. The physicians who agreed to participate in the study evaluated their lists and excluded patients who had died, left the practice, or were considered not suitable for the study because of lack of mobility, mental illness, or multiple comorbidities. Staff from each office then mailed letters signed by the physician notifying at-risk patients that they may have hypertension and requesting that they schedule an office visit for evaluation. One week after the letters were mailed, office staff telephoned the patients to answer questions and to schedule an office visit for an AOBP measurement. Up to 3 telephone calls were made in an attempt to reach each patient.

During the next 6 months, we used the BpTRU (Coquitlam BC, Canada) BPM-200 AOBP device to obtain multiple blood pressure measurements.^{18,19} Patients were seated in the examination room chair, and the appropriately sized cuff of the BpTRU device was applied. The automated blood pressure sequence was initiated by the medical assistant, who then left the patient alone in the examination room while the device obtained 6 measurements at 1-minute intervals. After discarding the first blood pressure reading, the BpTRU averaged the remaining 5 readings to produce an AOBP mean systolic and diastolic blood pressure measurement, or AOBP mean. The physician then entered the appropriate diagnosis into the EHR: primary or secondary hypertension (*ICD-9* 401.0-405.9), white-coat hypertension (796.2), prehypertension (796.2), or elevated blood pressure (796.2). Patients were considered to have hypertension if their mean systolic blood pressure was ≥ 135 mm Hg or mean diastolic blood pressure was ≥ 85 mm Hg. These cut points for hypertension are lower than those described in the seventh report of the Joint National Committee,²⁰ a generally accepted standard at the time of this study, and have been shown to correlate with daytime mean ambulatory blood pressure monitoring values, for which the accepted diagnostic cutoff for hypertension is 135/85 mm Hg.^{18,19}

To validate that phase 1 patients did not have undocumented hypertension (as opposed to undiagnosed hypertension), 2 authors (M.S. and C.M.M.) independently reviewed charts from a sample of phase 1 patients. Fifty (10.5%) of the 475 patients were chosen at random, and all physician office notes were examined during the review period (January 1, 2008, through December 31, 2010) for documentation of hypertension,

white-coat hypertension, prehypertension, elevated blood pressure, and/or use of any antihypertensive medications. After completion of independent reviews, the 2 physician reviewers met to resolve any discrepancies.

Phase 2: Quality Improvement and Follow-up

After phase 1, we established a continuous quality improvement initiative to further evaluate patients who remained at risk for undiagnosed hypertension. In this 24-month follow-up phase (phase 2), all primary care physicians received monthly lists of their patients who continued to be at risk for undiagnosed hypertension. These patients were contacted by staff via telephone or letter to arrange a follow-up appointment. These patients remained on the physicians' lists until an AOBP evaluation was completed or an ICD-9 diagnosis was entered into the chart that indicated the patient's at-risk status had been resolved. In addition, when an at-risk patient arrived for an office visit for any reason, a best practice advisory was prominently displayed on that patient's EHR screen to notify the medical assistant and physician that an AOBP measurement was needed.

Statistical Analysis

To compare those who completed an AOBP protocol in phase 1 with those who did not, we reviewed the EHRs of all eligible patients regarding their demographic and clinical characteristics. Our purpose was to assess whether the test characteristics of our screening algorithms could be applied to the potential phase 2 patients. We used a 2-sample *t* test for age and body mass index, a 2-sample *Z* test for proportions of comorbid conditions, and a Wilcoxon 2-sample test for systolic blood pressure and diastolic blood pressure to account for skewness. We used χ^2 tests to evaluate the association between categorical variables (eg, ethnicity) and patient inclusion. SAS 9.2 (SAS Corporation) was used for all calculations, and *P* < .05 was considered statistically significant. The positive predictive values of the computer-based hypertension screening algorithms were calculated by dividing the number of patients with an AOBP mean systolic blood pressure ≥ 135 mm Hg or mean diastolic blood pressure ≥ 85 mm Hg (true positives) by the number of at-risk patients identified by each screening algorithm (true positives plus false positives).

The Institutional Review Board of the NorthShore University HealthSystem approved this study.

RESULTS

Phase 1

There were 117 primary care physicians in the 23 practices who received a list of their patients that met the criteria of any of the 3 hypertension screening algo-

rithms. Of these physicians, 5 chose not to participate, and 8 did not follow the study protocol, leaving 104 physicians agreeing to participate in the study.

Figure 1 displays results of the EHR database query. Of the 139,666 active adult primary care patients in these 23 practices, 47,822 already had a diagnosis of hypertension, white-coat hypertension, prehypertension, or elevated blood pressure. The 3 screening algorithms for undiagnosed hypertension were applied to the remaining patients' EHRs. There were 1,586 patients who met the criteria of 1 or more of the algorithms and were therefore considered at risk for undiagnosed hypertension. Of this group, the participating physicians deemed 154 patients unsuitable

Figure 1. Flowchart of procedure for identifying patients at risk for undiagnosed hypertension.

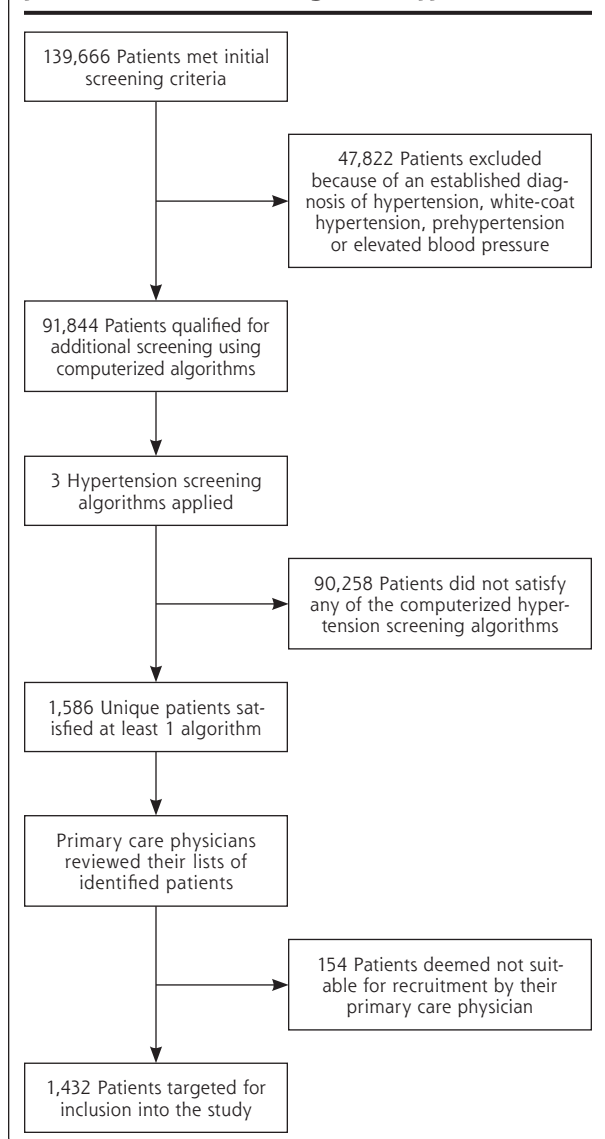


Table 1. Number of At-Risk Patients Identified by Each Hypertension Screening Algorithm

Algorithm	Number Identified
1. All patients whose 3 most recent encounters yielded a mean SBP >140 mm Hg or a mean DBP >90 mm. Encounters used were within 12 months before their most recent encounter	720
2. All patients who had 3 encounters with a SBP >140 or DBP >90 mm Hg within 12 months before their most recent encounter	968
3. Patients who had a single encounter with a SBP >180 or a DBP >100 mm Hg within 12 months before their most recent encounter	527
Unique patients identified by algorithms 1, 2, or 3	1,586

SBP = systolic blood pressure; DBP = diastolic blood pressure.

Note: All data were obtained from outpatient encounters with a primary care physician or specialist.

for the study, thus yielding 1,432 patients at risk for undiagnosed hypertension and eligible for inclusion.

Table 1 displays the 3 algorithms used to identify patients at risk for undiagnosed hypertension, the number of patients identified by each algorithm, and the number of unique patients identified by any of the 3 algorithms. As shown in Figure 2, each algorithm identified a substantial number of unique patients. Although overlap existed between and among algorithms, no single algorithm identified all of the patients at risk for undiagnosed hypertension, and only 25 patients met the criteria of all 3 algorithms.

Of the 1,432 patients targeted for AOBP testing, 475 completed an AOBP test during the 6 months of phase 1, and 957 did not. Table 2 compares the demographic and health characteristics of these phase 1 study patients. Phase 1 patients who completed AOBP measurements were older on average but were similar in every other respect to those who did not complete the AOBP testing. Table 3 illustrates the positive predictive values of the hypertension screening algorithms among the 475 phase 1 patients. Although the positive predictive values of the individual algorithms are higher than when all algorithms are considered together, combining the algorithms identified the greatest number of patients with hypertension.

Chart Review

The chart review of phase 1 study patients who completed AOBP measurements showed that the mean number of primary care and specialist physician office visits was 6.4 per year. A total of 960 clinic notes were reviewed. Only 2 of these 50 patients (4%) had notes in which the physician mentioned hypertension. Of these, 1 patient received antihypertensive medications and 1 did not. An additional 4 patients (8%) had elevated blood pressure documented by the physician. Of

these, 1 patient received an antihypertensive medication and 3 did not; therefore, only 2 of the 50 patients (4%) received antihypertensive medication despite not having an ICD-9 diagnosis corresponding to hypertension or elevated blood pressure.

Phase 2

Figure 3 illustrates the diagnostic outcomes among the 1,033 patients who remained active in the practices and were therefore observed during the 24-month phase 2 period. By the end of phase 2, 740 of 1,033 (72%) had received a diagnosis. Of these, 361 had hypertension, 290 had either white-coat hypertension, prehypertension, or elevated blood pressures, and 89 were considered to have normal blood pressure. A total of 293 (28%) patients neither completed an AOBP protocol nor had a hypertension-related ICD-9 diagnosis in their EHR. As a result, these patients remained at risk for undiagnosed hypertension. Based on this diagnostic resolution, the rate of being at risk for undiagnosed hypertension was 1.1/100 (1,033/91,844) before the phase 1 intervention. By the end of the phase 2 intervention, the rate of being at risk for undiagnosed hypertension had dropped to 0.3/100 (293/91,844).

DISCUSSION

This technology-based screening and testing approach successfully identified patients at risk for

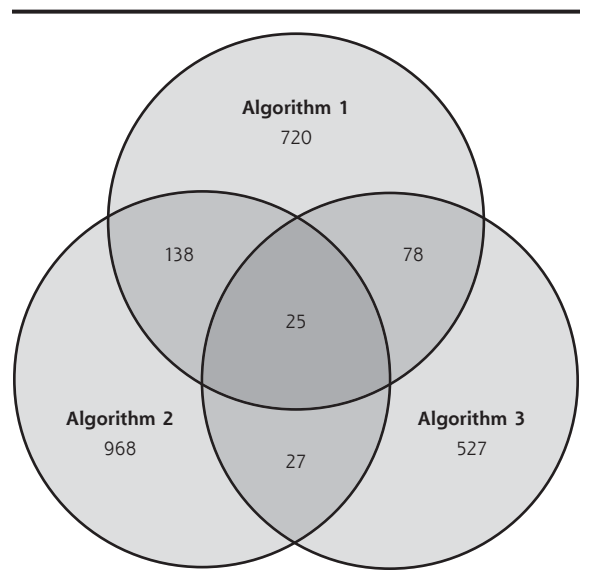
Figure 2. Overlap among hypertension screening algorithms.

Table 2. Characteristics of Phase 1 Study Patients Who Completed and Did Not Complete AOBP Measurements, at Baseline

Characteristic	Patients Who Completed AOBP (n = 475)	Patients Who Did Not Complete AOBP (n = 957)	P Value
Age, median γ (IQR)	54.4 (44.5-64.9)	50.1 (38.9-60.4)	<.01
Blood pressure, mean mm Hg (SD)			
Systolic	136.5 (9.35)	136.1 (9.76)	.46
Diastolic	82.3 (7.05)	82.5 (7.25)	.52
BMI, median kg/m ² (IQR)	29.6 (26.3-33.8)	30.1 (26.1-34.6)	.13
Sex, female, No. (%)	226 (47.6)	459 (48)	.89
Ethnicity, No. (%)			.36
African American	29 (6.1)	42 (4.4)	
Asian	13 (2.7)	26 (2.7)	
White	337 (70.9)	655 (68.5)	
Hispanic/Latino	16 (3.4)	42 (4.4)	
Other	80 (16.8)	192 (20.1)	
GERD, No. (%)	72 (15.2)	129 (13.5)	.39
Asthma, No. (%)	36 (7.6)	104 (10.9)	.05
Depression, No. (%)	36 (7.6)	75 (7.8)	.89
Diabetes mellitus, No. (%)	29 (6.1)	62 (6.5)	.77
COPD, No. (%)	10 (2.1)	16 (1.7)	.59
Coronary artery disease, No. (%)	5 (1.1)	13 (1.4)	.64
Congestive heart failure, No. (%)	2 (0.4)	7 (0.7)	.49
Prior myocardial infarction, No. (%)	1 (0.2)	2 (0.2)	.99

AOBP = ambulatory office blood pressure; PBMI = body mass index; COPD = chronic obstructive pulmonary disease; GERD = gastroesophageal reflux disease; IQR = interquartile range.

Table 3. Positive Predictive Values of Algorithms for Identifying Patients at Risk of Undiagnosed Hypertension Screening

Algorithm	Patient Identified as at Risk and Completed AOBP	Patient Hypertensive by AOBP ^a	PPV %	95% CI %
1	234	136	58	51-65
2	321	168	52	47-58
3	138	70	51	42-59
Any	475	249	52	48-57

AOBP = automated office blood pressure; PPV = positive predictive value.

^a Systolic blood pressure \geq 135 mm Hg or diastolic blood pressure \geq 85 mm Hg.

undiagnosed hypertension and classified most patients based upon their AOBP reading. In addition, the quality improvement initiative based upon this strategy reduced the rate of being at risk for undiagnosed hypertension over a 30-month period by more than 72% (1.1/100 to 0.3/100).

Prior studies have used algorithms to screen EHRs for chronic illnesses, including chronic kidney disease²⁶ and diabetes²⁷ based upon data such as estimated glomerular filtration rate or glycosylated hemoglobin. Diagnosing hypertension based upon EHR data, however, presents an additional challenge caused

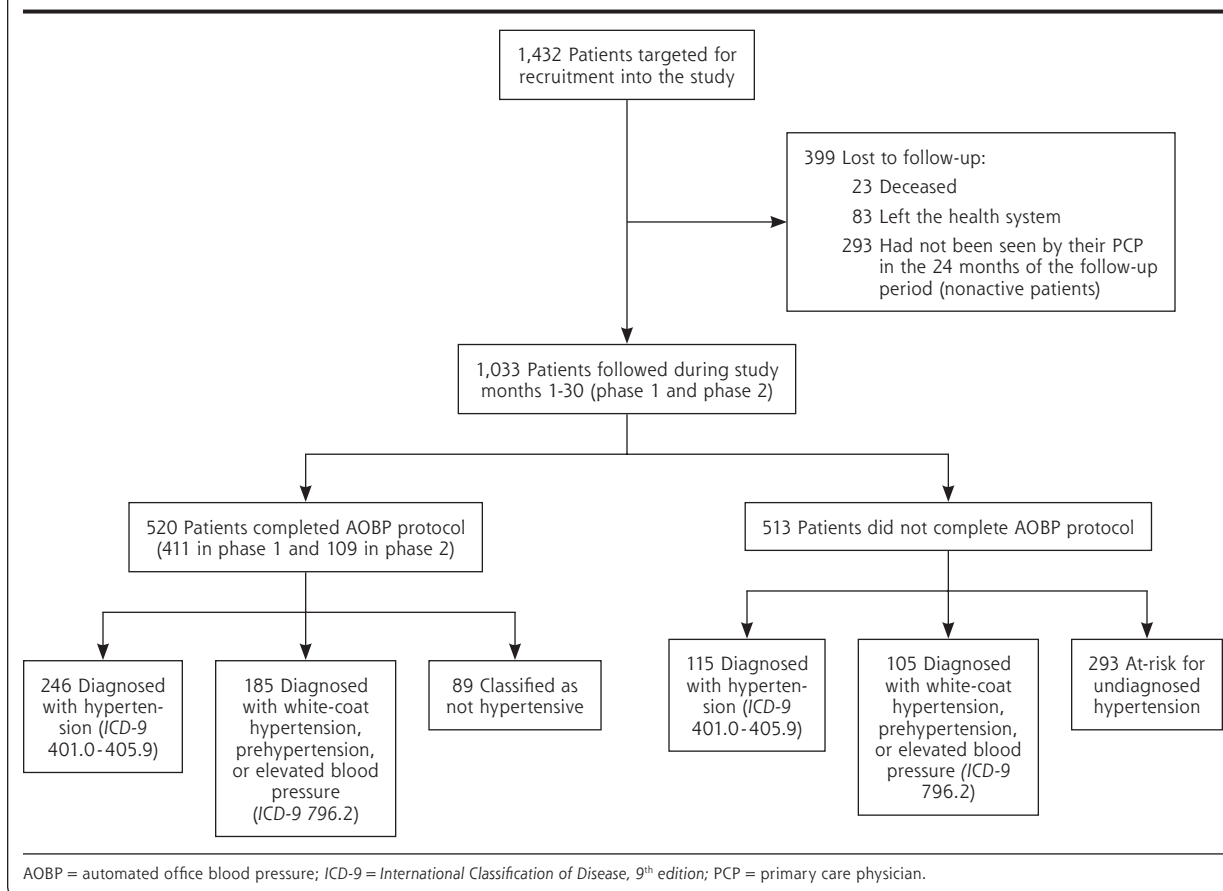
by variability in office-based blood pressure measurements.^{8,9} In addition, even when properly trained, physicians performing manual blood pressure measurements in the office obtain blood pressure values that overdiagnose hypertension compared with values obtained by trained research staff.¹⁰

To address this variability, the UK's National Institute for Health and Care Excellence recommends ambulatory blood pressure monitoring for all patients suspected of having hypertension.¹⁵ Given the obstacles associated with ambulatory blood pressure monitoring, our work raises an important and testable question: can algorithm-based screening of EHRs and AOBP testing be viewed as an acceptable alternative? Our results suggest that such a strategy is feasible and effective among patients with suspected hypertension.

A growing number of health systems have implemented EHRs and are developing databases that permit large-scale queries to support population health management strategies similar to this one. To reduce undiagnosed hypertension, we recommend the following multipronged approach: (1) application of hypertension screening algorithms to EHR databases to identify at-risk patients, (2) contacting at-risk patients to schedule AOBP measurements, (3) monthly written feedback to physicians regarding

at-risk patients who have yet to complete an AOBP measurement, and (4) electronic prompts for AOBP measurements whenever at-risk patients visit the clinic. In addition, until the positive predictive values of screening algorithms approach 100%, we also recommend AOBP measurement of any patient whose initial clinic blood pressure is \geq 140/90 mm Hg.

Certain caveats should be acknowledged with respect to dissemination of this approach. Although we used multiple algorithms to identify patients with elevated blood pressure readings, it is unlikely that we identified all patients with undiagnosed hyperten-

Figure 3. Flowchart of diagnostic resolution among cohort at risk for undiagnosed hypertension.

sion. Reducing the number of required office visits or the blood pressure cutoffs for positivity would almost certainly have increased our yield in identifying patients with undiagnosed hypertension, although this approach would have likely reduced each algorithm's positive predictive value. In addition, the positive predictive value is likely to vary in different populations depending upon the prevalence of undiagnosed hypertension. As a result, systems seeking to replicate this approach may need to establish optimal algorithms for their populations. Second, we did not compare the diagnostic accuracy of AOBP testing with ambulatory blood pressure monitoring among patients with suspected hypertension. Combining AOBP and ambulatory blood pressure monitoring measurements in future studies may confirm the value of the AOBP as an acceptable alternative. Third, our analysis did not include patients with rare or intermittent physician encounters. Improving access to health care systems and helping patients develop meaningful relationships with their physicians should increase the number of patients who can benefit from technology-based strategies to identify undiagnosed chronic disease.

With these caveats in mind, our experience suggests that such strategies have the potential to eliminate undiagnosed hypertension and may well be applicable to other common undiagnosed chronic diseases. Furthermore, similar methods can be adapted to assess and inform clinicians and patients on blood pressure control after the diagnosis of hypertension.

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