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Real-Time Electronic Medical Record Alerts Increase High Blood Pressure Recognition in Children

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Abstract

Objective—Pediatric hypertension remains largely unrecognized. We hypothesized that an electronic medical record (EMR) alert would increase elevated blood pressure (BP) recognition in a pediatric primary care setting.

Study Design—Pre–post evaluation of a real-time EMR alert and one-time provider educational session. A total of 1305 encounters of children 3 to 21 years with elevated intake BP and no prior hypertension diagnosis were included. Elevated BP recognition and relationship of recognition with cardiovascular disease (CVD) risk factors during the intervention was compared with an historical control.

Results—Recognition increased from 12.5% to 42% ($P < .001$). Recognition increased soon after alert implementation and was sustained without evidence of “alert fatigue.” During both periods, presence of CVD risk factors was associated with recognition. However, the magnitude was lesser in the intervention period.

Conclusions—Real-time EMR alerts substantially increase elevated BP recognition in children. However, underrecognition of elevated BP persisted, highlighting the need for additional strategies to improve provider recognition.

Keywords

computer alert; automated; triage; screening; hypertension; cardiovascular health; primary care; pediatrics; quality improvement; electronic health record

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Declaration of Conflicting Interests

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Authors' Note

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Introduction

Over the past several decades, pediatric hypertension (HTN) has increased in prevalence, and its importance in the overall cardiovascular (CV) health of children has been emphasized.¹ In addition to being associated with atherosclerosis in childhood, pediatric HTN is one CV disease (CVD) risk factor that has known clinical implications in adulthood.¹ As a result, guidelines published in 2004² and 2011¹ highlight annual blood pressure (BP) measurement of all children 3 years and older as one of the key strategies for CVD risk identification and reduction among children to decrease the burden and associated morbidity and mortality of CVD in adults.¹

Despite these guidelines, routine BP measurement,³ provider recognition of elevated BP, and diagnosis of pediatric HTN all remain low. We have previously shown that only 13% of elevated BPs measured in an urban academic pediatric primary care setting were recognized as elevated by providers.⁴ These results are similar to those obtained in a pediatric emergency department setting⁵ and in a large pediatric primary care setting.^{6,7}

Recognizing the many demands faced by primary care providers, we hypothesized that real-time electronic elevated BP alerts during clinic visits would increase recognition of elevated BP by eliminating the cumbersome steps for proper classification—specifically, the steps of determining a child's age- and sex-specific height percentile followed by determining their age-, sex-, and height percentile specific BP cutoffs. We also hypothesized that improving provider knowledge of guidelines would incrementally contribute to greater recognition. To test these hypotheses, we implemented and evaluated a 2-component intervention: ongoing real-time electronic medical record (EMR) alerts coupled with a one-time provider educational session.

Methods

We conducted an evaluation of a quality improvement and education initiative designed to improve provider recognition of elevated BP in children by comparing the intervention period with an historic control. The setting was an urban, academic primary care practice staffed by pediatric residents, adolescent medicine fellows, attending physicians, and nurse practitioners. All acute (same-day appointments and walk-in visits) and scheduled (well-child care and follow-up) encounters during the intervention period (January 1, 2009, to June 30, 2009) and scheduled encounters during the historical control period (January 1, 2006, to June 30, 2006) of patients 3 to 21 years of age with an elevated intake BP were included.

The historical control and intervention periods were chosen to capture a completely different cohort of resident providers, target the same time of year to minimize the impact of resident training level, and occur soon after alert implementation. Encounters were excluded if they were of children with a prior HTN diagnosis ($n = 105$); if BP was $<120/80$ and no height information was recorded within the previous 6 months ($n = 15$); or if the provider clinic note was missing ($n = 51$). This study was approved by an institutional review board of Johns Hopkins University School of Medicine.

Blood Pressure Measurement Protocol

In the practice, intake BP is measured via oscillometry by a nurse or nursing assistant prior to the provider encounter. All intake BPs, together with the patient's height and weight, were entered into the EMR and available to providers at the start of the visit during both periods.

Intervention

Alert—In September 2008, a real-time electronic alert was incorporated into the existing EMR to notify providers when an intake BP was elevated. All elevated BPs (≥ 90 th percentile for age/sex/height percentile¹ or $\geq 120/80$) generated an EMR alert that the BP was elevated and should be repeated. This alert served as a hard stop and could only be reconciled by selecting: “provider needs to obtain manual repeat” or “manual repeat completed” with the additional BPs entered in the EMR at that time. All BPs obtained by the nursing staff and all responses entered were immediately visible to the provider in the EMR.

Educational Session—A 30-minute educational session reviewing current BP measurement guidelines and HTN evaluation was offered to all resident providers who held a weekly continuity clinic at the study site ($n = 59$). This session was taught by the same person (TMB) during the regularly scheduled preclinic conference from January 12, 2009, to January 16, 2009. Resident providers who were not present for these sessions were provided the educational materials and instructed to review them independently ($n = 13$).

Data Collection and Variables

Each month during the intervention period we received a report of all encounters where an elevated BP alert was generated. The EMR for each encounter was reviewed manually by a research assistant who collected the following information from the visit: patient age, sex, self-reported race, medical history/comorbid conditions, family history of CVD (defined as one or more of the following: early myocardial infarction [≥ 55 years for men, ≥ 65 years for women], cerebrovascular accident, CVD, HTN, dyslipidemia), presence of hypertensive symptoms (one or more noted: headache, nausea, vomiting, shortness of breath/dyspnea, chest pain, palpitations), anthropometrics, and BP. In addition, data on provider type (resident, fellow, attending physician, or nurse practitioner) was recorded. Body mass index (BMI) and BMI z -score were calculated according to the 2000 Centers for Disease Control and Prevention Growth Charts.⁸ Children were categorized as being overweight/ obese if their BMI was ≥ 85 th percentile or ≥ 25 kg/m² if they were 20 years of age or older. All scheduled encounters in the historical control period were manually reviewed, first to identify the encounters of patients with an elevated BP and then, second, to abstract identical information as in the intervention period.

The outcome measure of the study was whether or not an elevated BP was recognized by the provider. An elevated BP was defined as recognized if any of the following were documented in the EMR by any provider at each encounter: (a) provider repeated BP by manual auscultation; (b) provider assessment included abnormal BP, elevated BP, or HTN; (c) provider plan included repeat BP or an evaluation for elevated BP.

Data Analyses

The overall prevalence of elevated BP recognition during the intervention period was compared with the prevalence in the historical control period by χ^2 analysis. Elevated BP during patient encounters were dichotomized as recognized versus not, and patient, clinic, and provider characteristics were compared between the 2 groups using Student's t test for continuous variables and χ^2 analyses for categorical variables. Univariate log-binomial regression was used to obtain the prevalence ratios of recognition by each characteristic, clustering by day of the week. This type of regression modeling was chosen over traditional logistic regression because it more directly models the proportion of encounters with recognized BP elevations. Log-binomial regression models the log of the prevalence (ie, proportion) whereas logistic regression models the log of the odds ratio (prevalence/1 – prevalence), which is an acceptable approximation of the prevalence for rare occurrences. As resident and attending providers have assigned clinic days, we clustered on day of the week to account for physician practice patterns. Prevalence ratios of recognition by each month in the intervention period compared with the historical control period were also studied. To investigate the impact of educational sessions on recognition of elevated BP, these monthly prevalence ratios were then adjusted for educational session attendance. In addition, the prevalence of recognition by demographic characteristics and CVD risk factors was compared between the periods using χ^2 analyses.

We conducted several sensitivity analyses. As designed, we used the average of all intake BPs to determine if a child's BP was elevated. Because providers may disregard the first measurement and instead use the most recent measurement in their assessment, we reanalyzed the data to determine recognition prevalence using only the most recent intake BP. We also explored the impact of including acute care visits in the intervention period by reanalyzing the data after excluding acute care encounters from that period. Analyses were conducted using Stata 11.0 (StataCorp, College Station, TX). A P value of $<.05$ was considered to be statistically significant.

Results

During the 6-month intervention period, there were 1305 encounters with elevated BP (Figure 1) out of 5919 total encounters of 3285 unique patients. Overall, 42% (556/1305) of encounters with an elevated BP were recognized in the intervention period compared with 12.5% (100/803) recognized during the control period ($P < .001$). The patient populations in each group were similar with few differences noted (Table 1).

The prevalence of recognition remained stable throughout the 6-month intervention period (Figure 2). In the intervention period, children who were older, non–African American, male, overweight/obese, or with a family history of CVD, a personal history of comorbid condition(s), or a systolic BP ≥ 120 mm Hg were more likely to have their elevated BP recognized (Table 1). Complaints of hypertensive symptoms, lack of a significant medical history, diastolic BP ≥ 80 mm Hg, provider type, and educational session attendance were not associated with recognition. During the intervention period, elevated BP was less likely to be recognized during an acute care visit than during a scheduled appointment.

Overall, recognition significantly increased from the control to the intervention period for each patient, clinic, and provider characteristic (Table 2). Within each period, there was no difference in recognition by provider type. Forty-seven of the 59 resident providers attended the educational session; recognition was no different when stratified by educational session attendance (Table 2).

The prevalence ratio (PR) of provider recognition was 2.6 to 3.7 times greater for each month in the intervention period compared with the control period overall (Table 3); this difference persisted after adjusting for educational session attendance ($P < .001$). Compared with scheduled encounters, acute care visit encounters were associated with significantly decreased recognition (Table 3). As observed in the control period, a systolic BP ≥ 120 mm Hg was associated with significantly greater recognition (PR = 1.3, 95% confidence interval [CI] = 1.2, 1.5; $P < .001$); however, the PR was not as large as observed during the control period (PR = 2.4, 95% CI = 1.5, 3.7; $P < .001$; Figure 3). Also, elevated BP encounters for children with increased CVD risk (presence of overweight/obesity, higher BMI z -score, family history of CVD) or with a known comorbidity were associated with greater provider recognition; however, as with systolic BP, the PRs were lower in the intervention period (Figure 3).

Several variables not associated with elevated BP recognition in the control period were significantly associated with increased recognition in the intervention period: older age, male sex, and non-African American (AA) race (Figure 3). Absence of significant medical history was no longer predictive of recognition in the intervention period (control PR = 0.4, 95% CI = 0.3, 0.7, $P < .001$; intervention PR = 1.1, 95% CI = 0.9, 1.3, $P = .5$).

Several sensitivity analyses were conducted. Of the 93 encounters in which a BP was repeated prior to the provider encounter, 17 (18%) BPs were normal on repeat. Recategorizing these BPs as “recognized” and excluding the 5 encounters with repeat BPs $< 120/80$ and no height measurement in the EMR, the rate of recognition increased slightly to 44% (573/1300). After excluding acute care encounters, the prevalence of recognition increased to 49% ($P = .003$, compared with control period).

Discussion

In this study of clinic encounters of patients 3 to 21 years of age without prior history of HTN in an urban, academic primary care center, we demonstrated that implementation of an automated EMR alert significantly increased provider recognition of elevated BP. The educational session that focused on proper BP measurement and elevated BP recognition and evaluation did not appear to affect recognition as demonstrated in adjusted and stratified analyses. Recognition increased soon after implementation and was sustained throughout the 6-month study period; there was no evidence of “alert fatigue,” that is, no decline in recognition after an initial peak. Many of the same characteristics associated with recognition in the control period⁴ were also associated in the intervention period; however, the magnitude of these associations significantly decreased. Overall, these results support the hypothesis that the complex steps required to recognize elevated BP in children hinder

recognition. Electronic alerts can replace the cumbersome process in which providers manually compare a patient's BP to the age/sex/height percentile BP tables.

As shown previously, patient characteristics that increase the risk of high BP were associated with greater recognition of elevated BP.⁴ Children with a greater BMI z-score or categorized as overweight/obese, those with a family history of CVD, and those with comorbid conditions such as diabetes or kidney disease were more likely to have their elevated BP recognized than were children without these characteristics. Interestingly, recognition was less influenced by the presence of these CVD risk factors in the intervention period. While many remained positively associated with recognition, the magnitude was significantly decreased. In fact, having no significant medical history neither increased nor decreased the probability of recognition, whereas previously this patient characteristic was associated with a 60% decrease in recognition. Similarly, healthy weight children with elevated BP were much less likely to have their elevated BP recognized than overweight/obese children in the control period. After implementation of the EMR alert, the PR of recognition increased from 0.4 to 0.8, providing evidence that these children were less likely to be missed. These findings imply that the alert helped bridge the gap between those with and without obvious CVD risk factors, allowing for enhanced recognition of elevated BP in those who would not otherwise appear to be at risk.

During the intervention period, elevated BP recognition was less dependent on extremely elevated BP. While systolic BP at or above the commonly recognized threshold of 120 mm Hg was 1.3 times more likely to be recognized than elevations below 120 mm Hg, this "advantage" was less prominent than in the control period when such a BP extreme was associated with a 2.4 times increase in recognition.

Several patient characteristics were associated with elevated BP recognition in the intervention period that were not associated in the control period. Males and AA children were more likely to have their elevated BP recognized than females and non-AA, respectively. Greater recognition of HTN in these patient groups has been shown in adults.⁹ The racial differences in recognition may reflect greater physician awareness of CVD risk in minority racial groups as suggested by Banerjee et al.⁹ The lack of an association prior to alert implementation may have been due to the poor rate of recognition overall or reduced statistical power because there were fewer clinical encounters with elevated BP in the control period than the intervention period.

Another notable finding is that the increase in recognition was sustained over the course of the 6-month study period. One of the main concerns providers have with computerized alerts is that they will become desensitized to alerts over time and less likely to notice and/or respond to them¹⁰ or more likely to override built-in hard stops.^{11,12} Results from our study dispel this concern.

While increasing provider awareness and education are essential elements of increasing recognition of elevated BP, this study suggests that simplification of a nonintuitive process is critical to achieving improved recognition in a pediatric population. A systematic review of studies evaluating the impact of provider education on clinical practice in the

management of HTN found only one randomized controlled trial utilizing formal CME training that resulted in a decrease in systolic BP but no long term change in diastolic BP, BMI, or pattern of BP medication use. Other randomized controlled trials found no change in BP control with formal CME or educational materials.¹³

While recognition of elevated BP did increase, over 55% of encounters with elevated BP in the intervention period remained unrecognized. With the increased prevalence of HTN and other CV risk factors and the mounting evidence that the origins of CVD are in childhood, further improvements in recognition are needed. While many of these children likely do not have HTN, as that is determined by the sustained elevation of BP over time, having intermittently elevated BP increases one's risk for the ultimate development of HTN. A child with a BP >95th percentile that normalizes on repeat measurement has a greater chance of developing HTN (1.4% incidence per year) than a child with normal BP (0.3% per year) or one with confirmed prehypertension (1.1% per year). Having a BP >95th percentile that decreases only to the prehypertensive range increases one's risk for developing HTN to an even greater degree (6.6% per year).¹⁴

Our study has limitations. First, recognition of elevated BP was defined by information obtained from completed provider clinic notes. It is possible that not all recognized elevations were documented in the EMR. In addition, 51 encounters did not have a transcribed clinic note to review, which may have influenced our results. Second, this study was unable to capture how many times a BP was not obtained. It is routine practice in this clinic to measure BP during all health care encounters, but we are unable to confirm whether or not this occurred. Third, there was a 3-year gap between the control and the intervention periods, raising concern for secular trends influencing results. While certainly possible, the guidelines for measurement of BP and diagnosis of hypertension were the same for each time period, having been published in 2004² and unchanged from the prior guidelines published in 1996.¹⁵ In addition, we used a control period 3 years before the intervention to capture a completely separate cohort of resident providers.

Finally, this study is a pre-post evaluation, not a randomized trial. While a cluster randomized trial would be ideal to assess this intervention, such trials can be logistically difficult, methodologically challenging, and expensive.¹⁶ Review of the literature reveals the paucity of such trials, but also describes the contribution other study designs, such as the one we employed, have had on improving diagnosis and treatment of various conditions.¹⁷ Finally, the intervention period included data from both scheduled clinic and acute care encounters, as opposed to the control period, in which data collection focused solely on scheduled clinic encounters. We opted to include acute care visits in the intervention period because it is standard of care to obtain a BP visit at all health care encounters, and regardless of the setting, an elevated BP should be recognized and repeated. Due to different methodologies in identifying clinic encounters with elevated BP (computer generated lists in the intervention period vs individual review of each scheduled encounter in the EMR in the control period), we were unable to collect data on acute visits in the control period. We therefore conducted a sensitivity analysis that excluded acute care encounters in the intervention period. This analysis revealed an increase in recognition prevalence from 42%

to 49% and suggests that the intervention may enhance recognition to a greater degree during regular scheduled visits.

Our study also has several strengths. To our knowledge, it is the first study that directly compares the impact of an electronic alert on recognition of elevated BP in a pediatric primary care population. Second, the study was conducted in a large, urban, academic center that serves a high-risk community. Third, it is likely that all encounters with elevated BP were detected. There was no reliance on chart screening to identify instances of elevated BP. Rather, monthly reports were generated listing each encounter where an alert occurred. Fourth, recognition was based on thorough chart review of clinic notes and did not rely on billing codes or administrative data. Finally, the intervention period spanned 6 months and clearly demonstrated that increased recognition was sustained without evidence for alert fatigue.

Conclusion

In conclusion, real-time EMR alerts can substantially increase provider recognition of elevated BP in children and hold considerable promise as a means to improve adherence to practice guidelines. However, underrecognition of elevated BP in children persists. Additional strategies to improve provider recognition are needed.

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Figure 1. Flow diagram of included encounters and provider recognition in the intervention period.
*Some providers repeated BP *and* planned an additional BP measurement/ordered an evaluation.

Figure 2.
Percentage of elevated blood pressure measurements recognized by providers during the pre-intervention and intervention periods.

Figure 3. Prevalence ratios of elevated blood pressure recognition by various characteristics during the pre-intervention and intervention periods.

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Abbreviations: CVD, cardiovascular disease; HTN, hypertension; SBP, systolic blood pressure; DBP, diastolic blood pressure.

d_i includes any of the following: obesity, metabolic syndrome, insulin resistance, diabetes mellitus, kidney disease or prematurity

Table 2

Prevalence of Recognized Elevated Blood Pressure in the Historical Control and Intervention Periods Stratified by Patient, Clinic, and Provider Characteristics.

Characteristic	Historical Control Period			Intervention Period			Pre vs Post	
	Number of Encounters With Elevated BP	% Recognized	P Value ^a	Number of Encounters With Elevated BP	% Recognized	P Value ^a	P Value ^b	
<i>Patient Demographics</i>								
Age								
12 years	452	12.0%	.67	753	45.4%	.02		<.001
<12 years	351	13.1%		552	38.8%			<.001
Sex								
Male	350	10.9%	.24	538	47.4%	.004		<.001
Female	453	13.7%		767	39.2%			<.001
Race								
African American	747	12.2%	.40	1216	41.9%	.05		<.001
Non-African American	56	16.1%		89	52.8%			<.001
<i>Medical History</i>								
Family history of CVD ^c								
Yes	48	22.9%	.04	105	58.1%	.003		<.001
No	753	11.7%		330	41.2%			<.001
Presence of comorbid conditions ^d								
Yes	164	24.4%	<.001	295	58.6%	<.001		<.001
No	639	9.4%		1010	37.9%			<.001
Past medical history								
Any	589	14.8%	.001	50	40.0%	.77		<.001
None	214	6.1%		1255	42.7%			<.001
<i>Clinical Measurements</i>								
Adiposity								
Overweight/obese ^e	388	18.6%	<.001	454	54.0%	.003		<.001
Healthy weight ^f	369	6.5%		370	43.2%			<.001
Blood pressure								
SBP 120 mm Hg	542	15.3%	<.001	835	46.8%	<.001		<.001

Characteristic	Historical Control Period			Intervention Period			Pre vs Post	
	Number of Encounters With Elevated BP	% Recognized	P Value ^a	Number of Encounters With Elevated BP	% Recognized	P Value ^a	P Value ^b	
SBP < 120 mm Hg	261	6.5%		470	35.1%		<.001	
DBP < 80 mm Hg	46	19.6%	.16	104	48.1%	.26	.001	
DBP < 80 mm Hg	752	12.0%		1201	42.1%		<.001	
<i>Provider Characteristics</i>								
Provider type								
Nurse practitioner	173	9.3%	.28	247	42.9%	.40	<.001	
Fellow/attending	78	10.3%		228	38.6%		<.001	
Resident	549	13.7%		830	43.6%		<.001	
Educational session attendance								
Resident attended ^g	N/A			499	42.7%	.52		
Resident did not attend	N/A			331	45.0%			
<i>Clinic Characteristics</i>								
Clinic type								
Resident clinic	549	13.7%	.11	830	43.6%	.35	<.001	
Nonresident clinic	251	9.6%		475	40.8%		<.001	

Abbreviations: BP, blood pressure; CVD, cardiovascular disease; SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index.

^aComparing prevalence of recognition by each characteristic within each time period (control *or* intervention period).

^bComparing prevalence of recognition between control and intervention period, by individual stratum of characteristics.

^cFamily history of any of the following: early myocardial infarction, cerebrovascular accident, cardiovascular disease, high cholesterol, hypertension.

^dComorbid conditions include past medical history of any of the following: obesity, metabolic syndrome, insulin resistance, diabetes mellitus, kidney disease, or prematurity.

^eBMI 85th percentile or BMI < 25 kg/m² if age < 20.

^fBMI < 85th percentile and < 25 kg/m² if > 20 years of age.

^g47/59 resident providers attended the educational session.

Table 3

Prevalence Ratio (PR) of Recognized Elevated Blood Pressure During the Historical Control and Intervention Periods by Month.

Variable	Unadjusted		
	PR	95% Confidence Interval	P Value
Study Period			
Historical control	Ref		
Intervention			
• Month 1	2.6	2.0, 3.4	<.001
• Month 2	3.6	3.0, 4.3	<.001
• Month 3	3.7	3.0, 4.6	<.001
• Month 4	3.0	2.2, 4.1	<.001
• Month 5	3.4	2.8, 4.2	<.001
• Month 6	3.6	2.7, 4.8	<.001
Acute care visit	0.6	0.4, 0.7	<.001