


ORIGINAL PAPER

Impact of updated pediatric hypertension guidelines on progression from elevated blood pressure to hypertension in a community-based primary care population

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Abstract

In 2017, definitions for pediatric hypertension were updated. A threshold of 130/80 mm Hg was introduced for stage 1 hypertension in adolescents, and children with obesity were removed from the reference population, lowering the 95th percentile, compared to the 2004 Fourth Report. The impact of these changes on care for youth with elevated blood pressure has not been well described. The objective of this study was to compare the 2017 and 2004 criteria for hypertension, evaluating how they impact estimates of risks for elevated blood pressure to progress to hypertension. Data came from youth 10-17 years of age with ≥ 2 elevated blood pressure measurements (≥ 90 th percentile or $\geq 120/80$ mm Hg) between 04/15/2014 and 04/14/2016 and three additional measurements over two subsequent years. Blood pressures were recorded in primary care practices within a large health system, as part of routine care. Rates of incident hypertension following persistent elevated blood pressure based on the 2017 guidelines vs the 2004 Fourth Report were compared. We found, among 2025 youth with persistent elevated blood pressure, 46% were female and mean age was 14.6 years. Over 2 years of follow-up, progression to hypertension occurred in 5.9% using the 2017 guidelines vs 1.1% using 2004 Fourth Report definitions. Using the 2017 criteria, progression was most common in older youth and those with obesity. In conclusion, for most youth, elevated blood pressure does not progress to hypertension within 2 years. However, progression from elevated blood pressure to hypertension was more than 5-fold greater when applying the 2017 guidelines compared to the older 2004 Fourth Report criteria.

1 | INTRODUCTION

Guidelines for hypertension in children and adolescents in the United States, published in 2004 as the Fourth Report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents (known as the Fourth Report),¹ defined hypertension as having blood pressure at or above the 95th percentile,

based on age-, sex-, and height-adjusted norms, at three ambulatory visits. Prehypertension was defined as having a single blood pressure between the 90th and 95th percentiles or $\geq 120/80$ mm Hg and < 95 th percentile. Based on these definitions, studies in ambulatory pediatric populations have reported the prevalence of hypertension to be 1%-3% and the prevalence of prehypertension to be as high as 30%.²⁻⁵ A prior school-based study found adolescents

with persistent prehypertension progressed to having hypertensive level blood pressures at a rate of 6.6% per year.⁶ Given this high risk for progression, older children and adolescents with elevated blood pressure are a relevant population to characterize and target for prevention of hypertension.

In 2017, the Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents (referred to as the 2017 guideline)⁷ updated definitions for hypertension. Because of their increased risk for hypertension, children and adolescents with obesity were not included in the 2017 guideline standard BP percentile tables. In addition, the 2017 guidelines defined hypertension in adolescents 13 to 17 years of age, as three or more blood pressure measurements at or above 130/80 mm Hg. As the 2017 adolescent hypertension definitions are a fixed number and not adjusted for height or weight, the systolic threshold for hypertension (130 mm Hg) is up to 9 mm Hg *higher*, with differences most notable in younger shorter adolescents, and the diastolic threshold (80 mm Hg) is up to 6 mm Hg *lower*, with the most substantial differences in older taller adolescents, compared to the 2004 Fourth Report percentile based definitions. For children ages 12 and younger, the new thresholds for the 90th and 95th percentiles for systolic and diastolic blood pressure are 1 to 4 mm Hg *lower* than the 2004 Fourth Report thresholds. In addition, the term “elevated blood pressure” has replaced prehypertension.⁷ Both the 2004 and the updated 2017 hypertension definitions are based on blood pressure distributions in reference populations and were not selected based on risks for adverse long-term outcomes.⁷

The potential impact of the updated definitions for hypertension on routine clinical care has not yet been thoroughly studied. The objective of this study was to determine to what extent the changes in definitions for hypertension introduced in the 2017 guidelines affected rates for progression from persistent elevated blood pressure to hypertension among youth in primary care when compared to definitions in the 2004 Fourth Report.

2 | METHODS

This retrospective cohort study was conducted in a large integrated health system in the upper Midwest. Data came from 21 primary care practices participating in a larger study of electronic decision support for elevated blood pressure and hypertension.⁸ Care of children and adolescents at these sites is provided by pediatric and family medicine physicians, pediatric and family practice nurse practitioners, and physician assistants. All sites use EpiCare© (Verona, WI) electronic health records (EHR), containing data on demographics, clinical encounters, diagnosis codes, and vital signs. Patient age, sex, and diagnosis codes were obtained for all patients from administrative databases. Self-reported or parent-reported race and ethnicity was obtained from EHR outpatient registration data.

2.1 | Study population

The study population consisted of patients 10-17 years of age with blood pressure measurements at primary care visits between 04/15/2014 and 04/14/2016 and with a valid height measurement in order to calculate a blood pressure percentile. Because the goal was to compare rates for developing incident hypertension, patients with a hypertension diagnosis (ICD-9-CM 401-405 or ICD-10-CM I10) prior to their index elevated blood pressure were excluded. Patients with two or more elevated blood pressure measurements (≥ 90 th percentile or $\geq 120/80$ mm Hg) followed by at least three separate primary care visits with blood pressure measurements over the subsequent 2 years of follow-up were retained in the cohort.

2.2 | Exposure and outcome measures

All sites used standardized procedures for height, weight, and blood pressure measurement as part of routine clinical care in community-based, primary care settings. Heights were measured with calibrated stadiometers and weights with calibrated scales and entered by clinic rooming staff in the EHR. Clinic staff were trained on appropriate patient positioning, cuff size, and placement of the blood pressure cuff, and blood pressure was measured as a single automated measurement using an oscillometric device (Omron, Omron Healthcare) with patients rested for 3 to 5 minutes prior to the blood pressure measurement. If the blood pressure was ≥ 95 th percentile, repeat measurement during the visit was recommended. Blood pressure percentiles for baseline visits were calculated based on age, gender, height, and blood pressure measurements recorded in the EHR, according to the 2004 Task Force Report.¹ If more than one blood pressure measurement was recorded at a given encounter, the average of the first and repeat measurement was used.

Blood pressure categories at baseline, for the period 04/15/2014-04/14/2016, were defined using the 2004 Fourth Report.¹ A patient was considered to have persistent elevated blood pressure, (previously defined as prehypertension), if the systolic or diastolic blood pressure recorded in the EHR was ≥ 90 th percentile or $\geq 120/80$ mm Hg at two primary care visits. The date of the second elevated blood pressure was assigned as the index date. Hypertension at follow-up was based on blood pressures measured at three subsequent and consecutive primary care visits within 2 years of the index date, with comparisons made between the 2004 Fourth Report thresholds (systolic or diastolic blood pressure ≥ 95 th percentile) and the 2017 guideline thresholds (systolic or diastolic blood pressure ≥ 95 th percentile for 10- to 12-year-olds or systolic or diastolic blood pressure $\geq 130/80$ mm Hg for 13- to 17-year-olds).

Additional covariates of interest included sex, race/ethnicity, insurance, age, and body mass index (BMI). Age and BMI were determined as of the index date. Age- and sex-specific BMI percentiles were calculated using the year 2000 Centers for Disease Control and Prevention (CDC) growth charts.⁹ BMI was classified into 3

categories: healthy (<85th percentile); overweight (85th- <95th percentile); and obese (\geq 95th percentile).

2.3 | Analytic methods

Patient characteristics were described in terms of mean, standard deviation, and percentage. The percentage of patients progressing to hypertension was computed using both the 2004 Fourth Report and 2017 guideline definitions of hypertension for all patients and for subgroups of patients stratified by sex, race, age, and BMI percentile. For patients with incident hypertension based on the 2017 guidelines, the pattern for their three hypertensive blood pressures was classified as: *systolic-only elevation* (ie, systolic blood pressures were \geq 130 mm Hg or 95th percentile and diastolic blood pressures were <95th percentile and <80 mm Hg), *diastolic-only elevation* (ie, diastolic blood pressures were \geq 80 mm Hg or 90th percentile and systolic blood pressures were <95th percentile and <130 mm Hg), *both elevated systolic and diastolic blood pressure*, or the pattern of three blood pressures included a *mixture of elevated systolic blood pressure or elevated diastolic blood pressure*. The number of patients progressing to hypertension with each blood pressure patterns is presented overall and by age at which blood pressure criteria were met. All statistical analyses were completed using SAS v9.4 (SAS Institute, Inc).

2.4 | Protection of human study subjects

This study was reviewed in advance, approved, and monitored by the HealthPartners Institutional Review Board with a waiver of informed consent.

3 | RESULTS

Of 5252 patients with two or more elevated blood pressures (\geq 120/80 mm Hg or \geq 90th percentile based on the 2004 Fourth Report) measured at 21 community-based primary care clinics from 4/15/14 to 4/14/16, 2025 (38.6%) had three subsequent blood pressures recorded within 2 years of their index visit and were included in the study cohort. As compared to the 3227 patients with 2 or fewer blood pressures during the 2-year follow-up period, those with 3 measurements were more likely to be female (46% vs 36%, $P<0.0001$) and were more likely to be white (75% vs 60% $P<0.0001$). Among the 2025 patients with 3 or more blood pressures during follow-up, progression to hypertension within 2 years occurred in 119 (5.9%) using the 2017 guideline definitions vs 22 (1.1%) using the 2004 Fourth Report definitions. (Table 1) Among the 357 blood pressures meeting criteria for hypertension using the 2017 definitions, 137 (38%) were based on the average of 2 or more measurements at a visit. Among the 66 blood pressures meeting criteria for hypertension using the Fourth Report definitions, 29 (44%) were based on the average of 2 or more measurements.

Based on either definition, progression to hypertension was about twice as common in youth with obesity (10.2% with 2017

guideline or 1.9% with 2004 Fourth Report) than in overweight or normal weight youth (<5% with 2017 guidelines or <1% with 2004 Fourth Report). Using the 2017 guideline, progression to hypertension increased markedly in youth who were 16 or 17 years old at the index visit (8.2% and 11.1%, respectively). Using the 2004 Fourth Report definitions, rates of progression were notably higher only for those who were 17 at their index visit.

In secondary analyses, using the 2017 guideline definitions, the pattern of blood pressure elevation varied by age for the 119 patients who progressed from elevated blood pressure to hypertension. Overall, 16.0% of patients progressed to hypertension based on only systolic blood pressure elevation, 23.5% had only diastolic blood pressure elevation, 5.0% had three blood pressures with systolic and diastolic elevation, and 55.5% had a mixture of elevated systolic and diastolic blood pressure (Table 2).

4 | DISCUSSION

In this retrospective cohort study of children and adolescents receiving primary care in a large integrated health system, only 1% of children with persistent elevated blood pressure progressed to hypertension over a two year period using blood pressure standards in the 2004 Fourth Report. In contrast, applying definitions published in the 2017 guidelines resulted in more than a 5-fold increase in rate of progression to hypertension. Thus, the updated definitions for hypertension will have a substantive impact in routine primary care practice. These analyses demonstrate that even small changes in the blood pressure thresholds used to define hypertension in youth can affect assessments of disease prevalence and our understanding of the risks associated with elevated blood pressure as a pre-disease state.

Updates to the hypertension guidelines for children and adolescents in the 2017 guidelines included removing children with obesity from the reference blood pressure tables and defining stage 1 hypertension as systolic or diastolic blood pressure \geq 130/80 mmHg for 13- to 17-year-olds. Introduction of the 2017 adult American College of Cardiology/American Heart Association guidelines has been estimated to increase hypertension prevalence in the US adult population from 31.9% to 45.6%.¹⁰ In similar analyses, using the 2017 guidelines, as compared to the 2004 Fourth Report on NHANES data, an increasing proportion of children would be classified as having hypertension or elevated blood pressure.¹¹ In a study of adolescents with obesity and type 2 diabetes, application of the 2017 guidelines, as compared to the 2004 Fourth Report, increased hypertension prevalence and identification of youth with target organ damage.¹² The present study further shows the effect of the 2017 guidelines on increasing the percentage of children with prevalent elevated blood pressure who may be at increased risk for development of hypertension.

The 2017 clinical practice guidelines recommend longitudinal observation for pediatric patients with elevated blood pressure because of their potential future risk of hypertension.⁷ There is a

TABLE 1 Progression to hypertension within 2 years of persistent elevated blood pressure (BP)

	N (%)	Progression to hypertension 2004 Fourth Report definitions ^a N (%)	Progression to hypertension 2017 guideline definitions ^b N (%)
All patients	2025 (100)	22 (1.1)	119 (5.9)
Female	934 (46.1)	16 (1.7)	50 (5.4)
Male	1091 (53.9)	6 (0.6)	69 (6.3)
Asian	73 (3.6)	0 (0)	3 (4.1)
Black	299 (14.8)	2 (0.7)	11 (3.7)
White	1517 (74.9)	20 (1.3)	99 (6.5)
Other/unknown	136 (6.7)	0 (0)	6 (4.4)
Hispanic ethnicity	112 (5.5)	0 (0)	4 (3.6)
Age at elevated BP index date ^c			
10	93 (4.6)	1 (1.1)	4 (4.3)
11	100 (4.9)	0 (0)	2 (2.0)
12	150 (7.4)	0 (0)	2 (1.3)
13	186 (9.2)	0 (0)	3 (1.6)
14	293 (14.5)	2 (0.7)	9 (3.1)
15	382 (18.9)	6 (1.6)	20 (5.2)
16	425 (21.0)	3 (0.7)	35 (8.2)
17	396 (19.6)	10 (2.5)	44 (11.1)
BMI percentile at elevated BP index date ^c			
<85th	1035 (51.1)	9 (0.9)	43 (4.2)
85-<95th	458 (22.6)	3 (0.7)	22 (4.8)
≥95th	532 (26.3)	10 (1.9)	54 (10.2)

^aAge 10-17: 3 consecutive BPs ≥95%, using 2004 Fourth Report percentile definitions.

^bAge 10-12: 3 consecutive BPs ≥95%, using updated percentile definitions. Age 13-17: 3 consecutive BPs ≥130/80 mm Hg.

^cElevated BP index date defined as date with second BP ≥90th percentile or ≥120/80 mm Hg.

TABLE 2 Characterizing blood pressure elevations for the blood pressures meeting criteria for hypertension based on the 2017 guideline definitions

	Elevated SBP only	Elevated DPB only	Elevated SBP and DBP	Mixture of elevated SBP or DBP
Age at index elevated BP ^a				
10 (n = 4)	2	0	0	2
11 (n = 2)	2	0	0	0
12 (n = 2)	0	0	0	2
13 (n = 3)	0	1	0	2
14 (n = 9)	2	2	0	5
15 (n = 20)	3	5	1	11
16 (n = 35)	5	11	2	17
17 (n = 44)	5	9	3	27
Total (N = 119)	19 (16.0)	28 (23.5)	6 (5.0)	66 (55.5)

Abbreviations: DBP, diastolic blood pressure; SBP, systolic blood pressure.

^aElevated BP index date defined as date with second BP ≥90th percentile or ≥120/80 mm Hg.

significant tracking effect for blood pressure between childhood and adulthood.¹³⁻¹⁷ Furthermore, in observational cohort studies, pediatric hypertension is associated with concurrent carotid intima-media

thickness¹⁸ and arterial stiffness in adults.¹⁹ Associations between blood pressure in adolescent and young adult populations and future mortality have also been reported.²⁰ In contrast, our findings

agree with prior studies that an isolated elevated blood pressure recorded at an ambulatory visit is likely to be lower when measured at subsequent clinic visits.²¹⁻²³ For instance, among approximately 300 adolescents within our health system with an isolated blood pressure ≥ 95 th percentile and follow-up measurement within 90 days, 76% were normotensive at follow-up.²¹ Similarly, in a multisite observational study of 6108 children and adolescents with an incident BP ≥ 95 th percentile, only 1.4% had two subsequent blood pressures meeting criteria for hypertension.²²

The 2017 clinical practice guidelines also may amplify the association between age, obesity, and progression from elevated blood pressure to hypertension. Our findings are in agreement with the widely recognized association between BMI and blood pressure in children and adolescents^{5,24-26} and the significant relationship between increasing BMI percentiles with increasing blood pressure percentiles.²⁶ The higher rates of progression to hypertension using 2017 criteria reinforce the need for longitudinal follow-up of older, obese adolescents with elevated blood pressure.

This study has potential limitations. First, because the data were obtained from electronic records, we were not able to assess the cuff size or arm used to measure blood pressure. Second, while the 2017 guidelines recommend auscultation, oscillometric devices were used for all blood pressure measurements as part of routine care in our ambulatory clinics. Nevertheless, all children were measured by personnel carefully trained in blood pressure, height, and weight measurement. Third, approximately 40% of children diagnosed with hypertension were based on an average of 2 or more measurements at a visit. For both the Fourth Report and 2017 definitions, progression to hypertension would likely have been lower if all elevated blood pressures had been remeasured at a given visit. Fourth, because follow-up time was truncated at 2 years, over 60% of patients with baseline elevated blood pressure did not have the 3 follow-up measurements required to definitively classify them as hypertensive. Finally, those lost to follow-up were more likely to be male and non-white race, potentially reducing the generalizability of our findings. Future studies should assess whether the observed relationships between elevated blood pressure and hypertension will be modified when longer follow-up is available.

5 | CONCLUSION

This study adds to the evidence that using the updated 2017 guideline definitions increases the prevalence of hypertension in children. Specifically, progression from persistent elevated blood pressure to hypertension was more than 5-fold higher when applying criteria in the 2017 guidelines as opposed to criteria in the 2004 Fourth Report.

CONFLICT OF INTEREST

The authors have no conflicts of interest relevant to this article to disclose.

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