Original Article

Undiagnosed hypertension among young adults with regular primary care use

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Objective: Young adults meeting hypertension diagnostic criteria have a lower prevalence of a hypertension diagnosis than middle-aged and older adults. The purpose of this study was to compare the rates of a new hypertension diagnosis for different age groups and identify predictors of delays in the initial diagnosis among young adults who regularly use primary care.

Methods: A 4-year retrospective analysis included 14 970 patients, at least 18 years old, who met clinical criteria for an initial hypertension diagnosis in a large, Midwestern, academic practice from 2008 to 2011. Patients with a previous hypertension diagnosis or prior antihypertensive medication prescription were excluded. The probability of diagnosis at specific time points was estimated by Kaplan–Meier analysis. Cox proportional hazard models (hazard ratio; 95% confidence interval) were fit to identify predictors of delays to an initial diagnosis, with a subsequent subset analysis for young adults (18–39 years old).

Results: After 4 years, 56% of 18–24-year-olds received a diagnosis compared with 62% (25–31-year-olds), 68% (32–39-year-olds), and more than 70% (≥40-year-olds). After adjustment, 18–31-year-olds had a 33% slower rate of receiving a diagnosis (18–24 years hazard ratio 0.66, 0.53–0.83; 25–31 years hazard ratio 0.68, 0.58–0.79) compared with adults at least 60 years. Other predictors of a slower diagnosis rate among young adults were current tobacco use, white ethnicity, and non-English primary language. Young adults with diabetes, higher blood pressures, or a female provider had a faster diagnosis rate.

Conclusion: Provider and patient factors are critical determinants of poor hypertension diagnosis rates among young adults with regular primary care use.

Keywords: delayed diagnosis, hypertension, young adults

Abbreviations: CI, confidence interval; EMR, electronic medical record; JNC 7, The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure; WCHQ, Wisconsin Collaborative for Healthcare Quality

INTRODUCTION

Hypertension is one of the leading preventable causes of death in the United States [1]. Blood pressures from young adulthood predict the incidence of future cardiovascular events [2]. Among young adults (18–39 years), approximately 20% of men and 15% of women have diagnosed hypertension, with an expected increase in prevalence due to high obesity rates [3].

According to the National Health and Nutrition Examination Survey (NHANES), rates of hypertension control have improved in the United States (defined per NHANES as an average SBP of <140 mmHg and diastolic pressure of <90 mmHg among patients with hypertension or self-reported current use of blood pressure-lowering medication) [4,5]. However, young adults have consistently low prevalence of hypertension control (38%) compared with middle-aged (40–59 years) and older (≥60 years) adults whose prevalence of control is 54 and 53%, respectively [4,6]. This is concerning because young adults with uncontrolled hypertension are at risk for chronic kidney disease and premature strokes, particularly in the presence of diabetes [3,7,8].

Unfortunately, prior studies report low hypertension diagnosis prevalence in young adults meeting criteria for hypertension [6,9]. Reasons for this disparity are largely unknown. Limited studies identifying barriers to hypertension diagnosis in young adults have focused on

lower primary care use and the lack of a regular source of primary care as contributing factors [6,10]. However, a previous study demonstrated that young adult and middle-aged women (18–49 years) are less likely to be diagnosed with hypertension within an obstetrics/gynecology clinic compared to internal medicine [11], suggesting that, even with healthcare utilization, encounter context may impact timely hypertension diagnosis. Studies in middle-aged and older primary care patients also demonstrated that insufficient clinic time and competing comorbidities contribute to diagnosis delays (clinical inertia) [12,13]. The purpose of our study was to determine the rate of initial hypertension diagnosis and predictors that contribute to faster or slower rates of diagnosis among younger and older adults with regular primary care who meet clinical hypertension criteria.

METHODS

Sample

This study was approved by the University of Wisconsin-Madison Institutional Review Board with a waiver of consent. The current study was a secondary analysis of clinical and administrative data from a large, Midwestern,

FIGURE 1 Study sample: enrollment and analysis. JNC 7, the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure; WCHQ, Wisconsin Collaborative for Healthcare Quality.

multidisciplinary academic group practice. To construct the study sample (Fig. 1), we first identified all patients at least 18 years old who met established criteria from the Wisconsin Collaborative for Healthcare Quality (WCHQ) [14,15] for being 'currently managed' in the practice between 1 January 2008 and 31 December 2011. WCHQ criteria are used in a statewide public reporting initiative to describe quality of care delivered by physician groups in Wisconsin. Patients are defined as currently managed by a primary care practice if a patient had at least two billable office encounters in an outpatient, nonurgent primary care setting, or one primary care encounter and one office encounter in an urgent care setting (regardless of diagnosis code), within 3 years, with at least one visit occurring in the prior 2 years [16]. These criteria were assessed for each of four calendar years for each patient. Patients were then evaluated for the first date they met clinical blood pressure eligibility criteria to receive a hypertension diagnosis. Patients were enrolled in the study on the first day they met criteria for blood pressure eligibility and for being currently managed. Blood pressure eligibility criteria were based on electronic medical record (EMR) data: at least three outpatient blood pressure measurements from three separate dates, at least 30 days apart, within a 2-year span (SBP $\geq$140 mmHg or DBP $\geq$90 mmHg) [1]; or two elevated blood pressures [11,17] (SBP $\geq$160 mmHg or DBP $\geq$100 mmHg), at least 30 days apart, but within a 2-year period. If more than one blood pressure was taken at a visit, the average was used [1]. Hospital and emergency room blood pressures were excluded. Patients continued to accrue time in the study until receiving a hypertension diagnostic code, the study ended, or censoring. Patients were censored if they died (censored day of death), were no longer currently managed (censored at the end of the year) [14,15], or achieved hypertension control prior to a diagnosis or hypertension treatment, defined as three consecutive normal blood pressures on three separate dates (<130/80 mmHg with diabetes or chronic kidney disease, otherwise <140/90 mmHg). The 365 days prior to study enrollment were used as a 'baseline period' to assess patients' baseline comorbidities and utilization.

To include patients only with incident hypertension, patients were excluded from analysis if, prior to the study start date, they had a hypertension diagnosis recorded in their EMR as defined by Tu *et al.* criteria [18] [ICD-9 code 401.x (essential hypertension), 402.x (hypertensive heart disease), 403.x (hypertensive renal disease), 404.x (hypertensive heart and renal disease), 405.x (secondary hypertension)], or any antihypertensive medication prescription. Patients who were pregnant during the study were excluded 1 year before, during, and 1 year after pregnancy using a modified approach developed by Manson *et al.* [19].

Primary outcome variable

The dependent variable was time (days) from the first date a patient met eligibility criteria to their initial hypertension diagnosis; results are reported in months. Diagnosis was defined by the first outpatient EMR entry of an ICD-9 code for hypertension, following Tu *et al.* criteria [18], an ICD-9 code of 796.2 for an 'elevated blood pressure without a diagnosis of hypertension' [20], or an antihypertensive
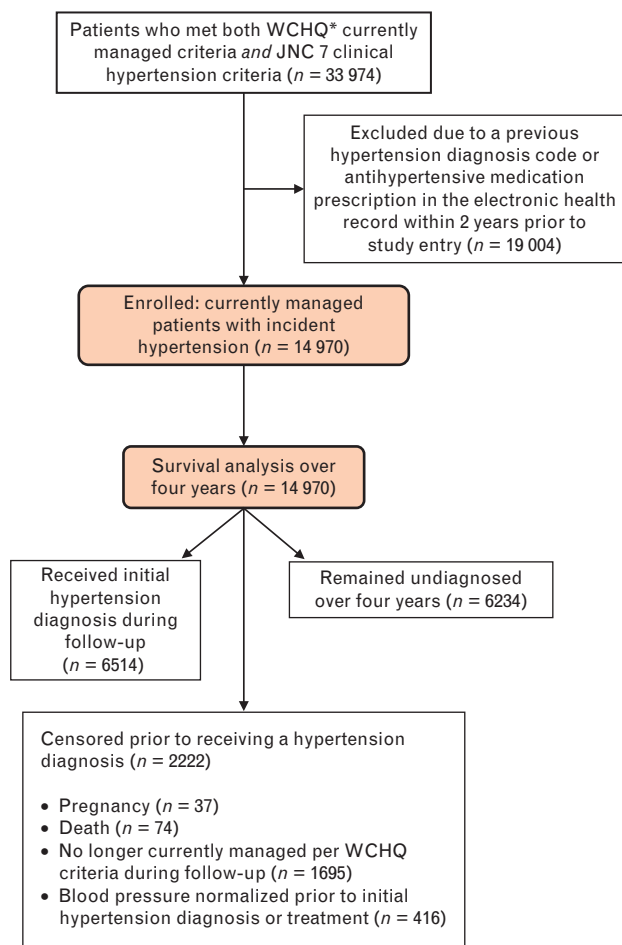
medication prescription (if it preceded the date of the first hypertension ICD-9 code).

Explanatory variables

The selection of explanatory variables to identify barriers to a hypertension diagnosis was guided by an established conceptual model of clinical inertia [21] and clinical judgment. Patient-related variables included age, sex, marital status, baseline tobacco use, baseline BMI, primary spoken language at home, ever receiving Medicaid, and stage of hypertension per the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC 7 criteria; Stage 1: 140–159/90–99 mmHg; Stage 2: ≥160/100 mmHg) [1]. Patients' baseline comorbidities were defined based upon ICD-9 codes per previously published, validated criteria. The Chronic Condition Warehouse algorithm was used to identify ischemic heart disease [22,23]; established algorithms were used to identify the presence of hyperlipidemia [24], diabetes mellitus [25], anxiety [26], chronic kidney disease [27], and peripheral vascular disease [28]. For low prevalence conditions, we created an indicator variable for the presence of any of the following [22,23]: atrial fibrillation, congestive heart failure, stroke/transient ischemic attack, other neurological disorders, collagen vascular disease, alcohol abuse, and deficiency anemia.

We constructed variables to describe baseline healthcare utilization patterns, which may influence the likelihood of receiving a hypertension diagnosis. The Johns Hopkins Adjusted Clinical Group (ACG) Case-Mix System (version 10.0) uses encounter data to generate a summary index score that reflects a patient's risk of subsequent resource utilization [29]. Additional measures included the number of primary care, specialty, and urgent care visits at baseline. Primary care visits included family medicine, internal medicine, obstetrics/gynecology, and pediatrics/adolescent medicine physicians (faculty, residents, fellows), nurse practitioners, and physician assistants [30,31].

Patients were assigned to a primary care provider based on patterns of outpatient face-to-face Evaluation & Management visits to physicians in the group as reported in professional service claims [16]. Each provider's age was obtained from the provider group's human resources office and the American Medical Association. Providers' specialties and sexes were acquired from human resources offices. The year of study entry was included as an explanatory variable (2008, 2009, 2010, 2011) to adjust for healthcare system and provider behavior over time [32].

Manual chart abstraction

Lifestyle counseling is a cornerstone to hypertension management, especially for young adults, but was not coded in the electronic health record. Therefore, we randomly selected 500 young adults (18–39 years old) and conducted a manual chart abstraction to assess the presence of documented lifestyle counseling within 1 year of meeting JNC7 clinical criteria for incident hypertension. The providers' progress notes and patient instructions were manually abstracted within the electronic health record for each face-to-face ambulatory visit to assess for the presence of any counseling topics per JNC7 guideline recommendations.

Statistical analysis

Analyses were conducted using Stata 10.0 (Stata-Corp, College Station, Texas, USA). Descriptive analysis was conducted for the manual chart abstraction data. Categorical variables were summarized using percentages; continuous variables were summarized using means (standard deviations). Univariate Kaplan–Meier survival curves were computed for age groups (18–24, 25–31, 32–39, 40–59, and ≥60 years) to evaluate the probability of obtaining a diagnosis as a function of time since meeting criteria. A multivariable Cox proportional hazards regression analysis was conducted using robust estimates of the variance to obtain adjusted hazard ratios and 95% confidence intervals (CIs) for explanatory variables associated with receiving an initial hypertension diagnosis among all age groups and young adults (18–39 years). Tests were considered significant at $P < 0.05$. Explanatory variables were considered for inclusion if statistically significant at $P < 0.2$ in Pearson correlations [33] and if the proportional-hazards assumption for the resultant model was not violated. Theoretically motivated interactions were tested between variables. The proportional-hazards assumption for the model was tested using a generalized linear regression of the scaled Schoenfeld residuals on functions of time [34].

RESULTS

Descriptive data

Overall, 14 970 patients met criteria for analysis (Table 1). Young adults (18–39 years) constituted 27% of the total sample. Among the 4023 young adults, 60% were male. Young adults had a higher percentage of ethnic minorities, current tobacco users, Medicaid use, and higher BMI than adults at least 40 years. Younger adults had more primary care and urgent care visits than patients at least 60 years old. Family medicine providers were more likely the provider for young adults than internal medicine providers. Provider age varied among patients; older providers were more likely to care for older adults.

Average follow-up was a mean (standard deviation) of 17 (13) months: 18–24-year-olds 15 (12), 25–31-year-olds 15 (12), 32–39-year-olds 16 (13), 40–59-year-olds 17 (13), at least 60-year-olds 17 (13). In the first 3 years, 14% ($n = 574$) of 18–39-year-olds were censored due to no longer meeting currently managed criteria, compared with 10% ($n = 1121$) of adults at least 40 years old.

Hypertension diagnosis rates

Kaplan–Meier curves demonstrated that young adults had a lower diagnosis rate than middle-aged and older adults (Fig. 2). After 2 years, only 39% of 18–24-year-olds compared with 43% (25–31-year-olds), 49% (32–39-year-olds), and 54% (≥40-year-olds) received a diagnosis. After 4 years, 56% of 18–24-year-olds compared with 62% (25–31-year-olds), 68% (32–39-year-olds), 71% (40–59-year-olds), and 73% (≥60-year-olds) received a diagnosis. Among patients who received a hypertension diagnosis, the mean time to diagnosis was 6 months or less (Table 2) with no significant difference by age groups.

TABLE 1. Baseline demographics by age group

		By age group					
	Total population N = 14970	18–24 years N = 573 (3.8%)	25–31 years N = 1365 (9.1%)	32–39 years N = 2085 (14%)	40–59 years N = 7396 (49%)	≥60 years N = 3551 (23%)	P value
Patient characteristics							
Age, years, mean (SD)	50 (15)	22 (2.1)	29 (2.0)	36 (2.4)	50 (5.6)	69 (7.8)	<0.001
Female, n (%)	7409 (49)	227 (40)	554 (41)	843 (40)	3702 (50)	2083 (59)	<0.001
Marital status, n (%)							<0.001
Single	4169 (28)	520 (91)	795 (58)	700 (34)	1658 (22)	496 (14)	
Married/partnered	8910 (60)	44 (7.7)	516 (38)	1238 (59)	4857 (66)	2255 (64)	
Separated/divorced/widowed/other	1891 (13)	9 (1.6)	54 (4.0)	147 (7.1)	881 (12)	800 (23)	
Race/ethnicity, n (%)							<0.001
White	13224 (88)	474 (83)	1136 (83)	1732 (83)	6561 (89)	3321 (94)	
Black	714 (4.8)	52 (9.1)	108 (7.9)	165 (7.9)	352 (4.8)	37 (1.0)	
Other[a]	1032 (6.9)	47 (8.2)	121 (8.9)	188 (9.0)	483 (6.5)	193 (5.4)	
Tobacco use, n (%)							<0.001
Current tobacco use	2653 (18)	150 (26)	357 (26)	454 (22)	1397 (19)	295 (8.3)	
Former tobacco use	3686 (25)	67 (12)	275 (20)	434 (21)	1672 (23)	1238 (35)	
Never used tobacco	6375 (43)	283 (49)	516 (38)	879 (42)	3191 (43)	1506 (42)	
Unknown/missing	2256 (15)	73 (13)	217 (16)	318 (15)	1136 (15)	512 (14)	
BMI, kg/m^2, mean (SD)	31 (8.4)	33 (12)	33 (8.4)	33 (8.1)	31 (6.8)	29 (10)	<0.001
Female, mean (SD)	31 (8.1)	35 (11)	34 (9.5)	35 (9.0)	31 (7.7)	28 (6.3)	<0.001
Male, mean (SD)	31 (5.9)	30 (7.8)	31 (6.9)	32 (6.6)	31 (5.5)	29 (4.8)	<0.001
Primary spoken language, n (%)							<0.001
English	13798 (92)	512 (89)	1200 (88)	1899 (91)	6872 (93)	3315 (93)	
Other	1172 (7.8)	61 (11)	165 (12)	186 (8.9)	524 (7.1)	236 (6.7)	
JNC 7 stage of hypertension,[b] n (%)							0.043
Stage 1: 140–159/90–99 mmHg	11460 (77)	456 (80)	1062 (78)	1622 (78)	5591 (76)	2729 (77)	
Stage 2: ≥160/100 mmHg	3510 (23)	117 (20)	303 (22)	463 (22)	1805 (24)	822 (23)	
Baseline comorbid conditions, n (%)							
Hyperlipidemia	2968 (20)	18 (3.1)	76 (5.6)	226 (11)	1494 (20)	1154 (33)	<0.001
Diabetes mellitus	771 (5.2)	19 (3.3)	26 (1.9)	78 (3.7)	370 (5.0)	278 (7.8)	<0.001
Anxiety	2008 (13)	115 (20)	267 (20)	322 (15)	995 (13)	309 (8.7)	<0.001
Chronic kidney disease	166 (1.1)	2 (0.4)	8 (0.6)	17 (0.8)	65 (0.9)	74 (2.1)	<0.001
Ischemic heart disease	272 (1.8)	1 (0.2)	2 (0.2)	7 (0.3)	86 (1.2)	176 (5.0)	<0.001
Peripheral vascular disease	224 (1.5)	0 (0.0)	3 (0.2)	6 (0.3)	63 (0.9)	152 (4.3)	<0.001
On Medicaid ever,[c] n (%)	1449 (9.7)	115 (20)	260 (19)	339 (16)	659 (8.9)	76 (2.1)	<0.001
ACG[d] score, young, mean (SD)	1.6 (2.0)	1.1 (1.4)	1.0 (1.3)	1.1 (1.2)	1.6 (1.9)	2.4 (2.5)	<0.001
Baseline ambulatory visit counts, annual, mean (SD)							
Primary care visits	2.6 (2.5)	2.9 (3.2)	2.7 (2.7)	2.7 (2.6)	2.5 (2.4)	2.4 (2.2)	<0.001
Specialty care visits	2.3 (3.1)	2.0 (3.0)	2.1 (2.7)	2.0 (2.7)	2.1 (2.9)	3.0 (3.8)	<0.001
Urgent care visits	0.5 (1.1)	0.9 (1.6)	1.0 (1.6)	0.8 (1.2)	0.5 (1.0)	0.3 (0.7)	<0.001
Provider characteristics							
Female, n (%)	6742 (45)	256 (45)	624 (46)	942 (45)	3340 (45)	1580 (44)	0.21
Specialty providing majority of ambulatory care, n (%)							<0.001
Internal medicine	5492 (37)	108 (19)	390 (29)	593 (28)	2628 (36)	1773 (50)	
Family medicine/family practice	7507 (50)	321 (56)	777 (57)	1221 (59)	3791 (51)	1397 (39)	
Other	1971 (13)	144 (25)	198 (15)	271 (13)	977 (13)	381 (11)	
Age,[e] years, mean (SD)	46 (11)	44 (11)	42 (10)	44 (11)	46 (11)	49 (11)	<0.001

N, numerator.
[a]Other ethnicities: Hispanic/Latino (1.9%); Asian (1.5%); Native Hawaiian/Pacific Islander (0.5%); American Indian/Alaska Native (0.3%); Unknown (2.7%).
[b]JNC 7 Stage of hypertension = severity of blood pressure elevation at study entry.
[c]On Medicaid at any point during the baseline or study period.
[d]ACG = Adjusted Clinical Group Case-Mix Assessment System.
[e]AMA is the source for the raw physician data (provider ages only); statistics, tables, or tabulations were prepared by User-Customer (M.A.S., H.M.S.) using AMA Masterfile data (Identification of who owns the file and who used the file is required by the AMA data use agreement).

Predictors of time to hypertension diagnosis (all adults)

Unadjusted Cox proportional hazards models (Table 3) demonstrated that 18–39-year-olds had a slower rate of receiving an initial hypertension diagnosis. Adjusting for patient demographics, comorbidities, and provider factors, adults 18–24 years (hazard ratio 0.66; 0.53–0.83),

25–31 years (hazard ratio 0.68; 0.58–0.79), and 32–39 years (hazard ratio 0.85; 0.75–0.96) had slower rates of receiving a diagnosis than adults at least 60 years old.

Patients with slower diagnosis rates had higher urgent care use, intermittently normal baseline blood pressures, or currently used tobacco. Patients with faster diagnosis rates had diabetes, chronic kidney disease, a higher BMI,
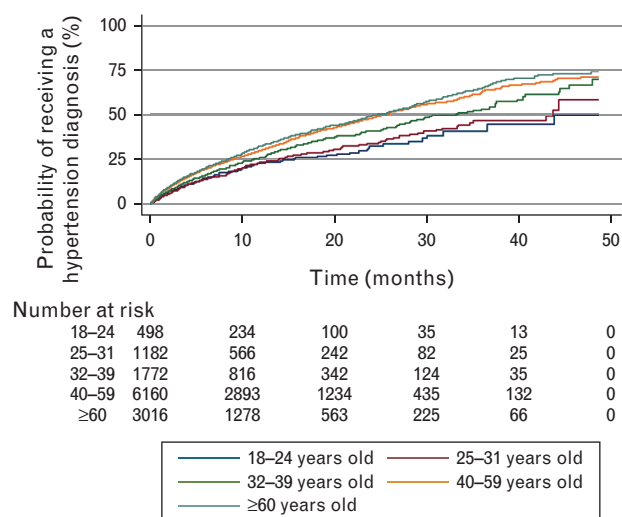
FIGURE 2 Kaplan–Meier estimates: likelihood of a hypertension diagnosis over 4 years.

were African–American, or received Medicaid. Providers in the third and highest age quartiles ($\geq$46 years) had lower diagnosis rates; female providers had higher rates.

Patients with stage 2 hypertension had faster diagnosis rates than patients with stage 1 hypertension. However, the effect of stage 2 hypertension on time to diagnosis differed by study start year ($\chi^2 = 9.47$; $P = 0.024$). Patients with stage 2 hypertension and a 2008 enrollment year had a 28% slower diagnosis rate than stage 2 patients with a 2011 start year. There was not a significant interaction between study start year and age ($\chi^2 = 14.8$; $P = 0.253$). The global test P value for the proportional-hazards assumption was 0.057 for all adults (Table 3).

Predictors of time to hypertension diagnosis among young adults

Unadjusted Cox proportional hazards limited to young adults (18–39 years old) demonstrated that 18–24-year-olds (hazard ratio 0.77; 0.63–0.95) and 25–31-year-olds (hazard ratio 0.81; 0.70–0.94) received diagnoses at slower rates than 32–39-year-olds (Table 4). After adjustment, age remained a significant predictor of a slower diagnosis rate among 18–31-year-olds than among 32–39-year-olds.

Cox proportional hazard models restricted to young adults (18–39) demonstrated slower diagnosis rates among 18–39-year-olds who had a non-English primary home language, intermittently normal baseline blood pressures, were white, or current tobacco users. Young adults had a

faster diagnosis rate if they had diabetes, Stage 2 hypertension, a female primary care provider, or were female. Study start year was not a significant predictor among young adults ($\chi^2 = 5.98$; $P = 0.113$). Provider specialty was not associated with diagnosis rates among young adults. The global test P value for the proportional-hazards assumption was 0.172 among young adults (Table 4).

Documented lifestyle counseling among young adults

Among a subgroup of 500 randomly selected young adults, mean age 32 years (SD = 5.6 years), 45% ($n = 225$) did not have any documented lifestyle counseling within 1 year of meeting criteria for incident hypertension. The majority of young adults (53%) had a documented family history of hypertension or premature coronary artery disease.

DISCUSSION

Our sentinel findings demonstrate that young adults who meet criteria for a hypertension diagnosis, even with regular primary care use, have a slower rate of receiving an initial diagnosis than middle-aged and older adults. Kaplan–Meier curves demonstrated that at 4 years, 56% of 18–24-year-olds, 62% (25–31-year-olds), and 68% (32–39-year-olds) received an initial hypertension diagnosis. However, among adults who received a hypertension diagnosis, the time to diagnosis between age groups was not remarkably different.

Previous research suggests that the lack of a regular source of primary care is a significant contributor to gaps in hypertension control among young adults [6]. We demonstrated that even among adults with regular primary care access, 18–39-year-olds were unlikely to receive a hypertension diagnosis compared with adults at least 40 years old. This study extends previous research examining predominantly middle-aged and older adults describing clinical inertia in diagnosing hypertension [12,13,35]. Our research determined multifactorial predictors of clinical inertia contributing to a slower rate of hypertension diagnosis in the young adult population. However, none of the variables fully explained the diagnostic inertia related to age.

In our study, among young adults, language and ethnicity were significantly associated with a delayed hypertension diagnosis. Young adults whose primary home language was not English had a 41% slower diagnosis rate. This supports previous research in predominantly older adults that language barriers significantly affect the diagnosis of hypertension [36]. This highlights the

TABLE 2. Time to a hypertension diagnosis in months, among diagnosed patients

	Diagnosed population (N)	Median (months)	Mean (months)	Standard deviation
Total population	6514	1.5	5.6	8.4
By age group				
18–24 years old	188	0.9	4.6	7.7
25–31 years old	465	1.1	5.1	8.1
32–39 years old	826	1.3	5.4	8.3
40–59 years old	3412	1.4	5.7	8.4
$\geq$60 years old	1623	1.9	6.0	8.8

TABLE 3. Hazard ratios and 95% confidence intervals of independent predictors of a hypertension diagnosis (all participants, *N* = 14970)

Variable	Unadjusted HR	95% CI	*P* value	Adjusted HR	95% CI	*P* value
Patient factors						
Age						
18–24 years	0.60	(0.50–0.73)	<0.001	0.66	(0.53–0.83)	<0.001
25–31 years	0.63	(0.56–0.72)	<0.001	0.68	(0.58–0.79)	<0.001
32–39 years	0.78	(0.71–0.87)	<0.001	0.85	(0.75–0.96)	0.007
40–59 years	0.95	(0.88–1.0)	0.13	0.98	(0.90–1.1)	0.56
≥60 years	1.0	–	–	1.0	–	–
Race/ethnicity						
White				1.0	–	–
Black				1.4	(1.2–1.6)	<0.001
Other				1.1	(0.99–1.3)	0.07
Marital status						
Single				1.0	–	–
Married/partnered				1.0	(0.96–1.1)	0.31
Separated/divorced/widowed/other				1.1	(0.98–1.2)	0.10
Tobacco use						
Current tobacco use				0.89	(0.81–0.98)	0.023
Former tobacco use				1.0	(0.96–1.1)	0.39
Never used tobacco				1.0	–	–
Unknown/missing				1.1	(1.0–1.2)	0.029
BMI				1.004	(1.001–1.007)	0.023
On Medicaid during baseline or study period				1.2	(1.1–1.4)	0.002
Comorbid conditions						
Diabetes mellitus				1.4	(1.2–1.6)	<0.001
Anxiety				1.1	(0.97–1.2)	0.17
Chronic kidney disease				1.5	(1.1–2.0)	0.010
Low prevalence condition[a]				1.1	(0.93–1.2)	0.35
ACG[b] risk score, young index				1.02	(1.00–1.04)	0.09
Intermittent normal blood pressures in baseline				0.79	(0.73–0.85)	<0.001
JNC 7 Stage of hypertension[c]						
Stage 1: 140–159/90–99 mmHg				1.0	–	–
Stage 2: ≥160/100 mmHg				2.0	(1.6–2.7)	<0.001
Study start year						
2008				1.2	(1.0–1.4)	0.021
2009				1.0	(0.89–1.2)	0.65
2010				1.0	(0.85–1.2)	0.99
2011				1.0	–	–
2008 start year x Stage 2 hypertension$_{int}$				0.72	(0.55–0.95)	0.021
2009 start year x Stage 2 hypertension$_{int}$				0.89	(0.66–1.2)	0.45
2010 start year x Stage 2 hypertension$_{int}$				0.86	(0.62–1.2)	0.37
2011 start year x Stage 2 hypertension$_{int}$				1.0	–	–
Total ambulatory visit counts, annual mean						
Primary care visits				0.99	(0.98–1.0)	0.55
Urgent Care visits				0.96	(0.921–0.996)	0.030
Provider factors						
Primary specialty						
Internal medicine				1.0	–	–
Family medicine/family practice				1.0	(0.94–1.1)	0.77
Other				0.98	(0.88–1.1)	0.66
Provider age						
Lowest provider age quartile				1.0	–	–
2nd provider age quartile				1.0	(0.91–1.1)	0.99
3rd provider age quartile				0.87	(0.79–0.96)	0.005
Highest provider age quartile				0.87	(0.79–0.95)	0.003
Provider sex						
Female				1.2	(1.1–1.3)	<0.001

CI, confidence interval; HR, hazard ratio.
[a]Due to low prevalence, an indicator variable was created for the presence of any of the following comorbidities: atrial fibrillation, congestive heart failure, stroke/transient ischemic attack, other neurological disorders, collagen vascular disease, alcohol abuse, or deficiency anemia.
[b]ACG = Adjusted Clinical Group Case-Mix Assessment System.
[c]JNC 7 Stage of Hypertension = severity of blood pressure elevation at study entry.

importance of addressing communication barriers to improve cardiovascular risk factor management among adults whose primary language is not English. In contrast, African–Americans had a faster diagnosis rate than patients of white ethnicity. Results from the National Health Interview Survey demonstrated that African–Americans are more likely to know they have hypertension [4]. Interestingly, patient behavior, specifically tobacco use, significantly decreased the rate of diagnosis. Young adults currently using tobacco had a 24% slower rate of receiving a

TABLE 4. Hazard ratios and 95% confidence intervals of independent predictors of a hypertension diagnosis (young adults, N = 4023)

Variable	Unadjusted HR	95% CI	P value	Adjusted HR	95% CI	P value
Patient factors						
Age						
18–24 years	0.77	(0.63–0.95)	0.014	0.76	(0.61–0.95)	0.018
25–31 years	0.81	(0.70–0.94)	0.004	0.79	(0.68–0.93)	0.004
32–39 years	1.0	–	–	1.0	–	–
Sex						
Female				1.2	(1.03–1.42)	0.023
Race/ethnicity						
White				0.73	(0.57–0.94)	0.013
Black				1.1	(0.76–1.5)	0.70
Other				1.0	–	–
Tobacco use						
Current tobacco use				0.76	(0.62–0.93)	0.007
Former tobacco use				0.95	(0.79–1.1)	0.61
Never used tobacco				1.0	–	–
Unknown/missing				1.0	(0.83–1.2)	0.90
BMI				1.006	(0.999–1.014)	0.11
Primary spoken language						
English				1.0	–	–
Other				0.59	(0.43–0.79)	0.001
On Medicaid during baseline or study period				1.2	(0.96–1.4)	0.12
Comorbid conditions						
Diabetes mellitus				1.6	(1.1–2.3)	0.006
Anxiety				1.2	(1.0–1.5)	0.049
ACG[a] risk score, young index				1.0	(0.97–1.1)	0.38
Intermittent normal blood pressures in baseline				0.74	(0.63–0.87)	<0.001
JNC 7 Stage of hypertension[b]						
Stage 1: 140–159/90–99 mmHg				1.0	–	–
Stage 2: ≥160/100 mmHg				1.8	(1.5–2.1)	<0.001
Study start year						
2008				1.0	–	–
2009				1.1	(0.92–1.3)	0.31
2010				0.87	(0.71–1.1)	0.21
2011				0.83	(0.63–1.1)	0.17
Total ambulatory visit counts, annual mean						
Primary care visits				0.88	(0.79–0.99)	0.036
Specialty visits				1.0	(0.99–1.1)	0.10
Urgent care visits				0.94	(0.87–1.0)	0.15
Provider factors						
Primary specialty						
Internal medicine				1.0	–	–
Family medicine/family practice				0.91	(0.76–1.1)	0.26
Other				0.93	(0.74–1.2)	0.52
Provider age						
Lowest provider age quartile				1.0	–	–
2nd provider age quartile				1.1	(0.88–1.3)	0.57
3rd provider age quartile				0.93	(0.75–1.1)	0.47
Highest provider age quartile				0.97	(0.79–1.2)	0.75
Provider sex						
Female				1.3	(1.1–1.5)	0.001

CI, confidence interval; HR, hazard ratio.
[a]ACG = Adjusted Clinical Group Case-Mix Assessment System.
[b]JNC 7 Stage of Hypertension = severity of blood pressure elevation at study entry.

diagnosis. A similar trend was previously documented among young female current tobacco users [11]. Among patient comorbidities, young adults with diabetes had a faster rate of hypertension diagnosis. As almost 90% of patients with diabetes have one or more additional chronic conditions, this finding may reflect concordant risk perceptions for diabetes and hypertension as a cue for care [37].

Provider factors also contributed to hypertension diagnosis delays. Contrary to previous literature, a provider's specialty was not a significant predictor for an initial diagnosis in young adults [11]. However, female providers had a faster rate of diagnosis in young adults. In previous research, female providers have demonstrated greater 'partnership-building skills' and longer visits than male providers [38]. In addition, young adults with Stage 1 hypertension had a slower rate of diagnosis than patients with higher blood pressures. According to previous studies, primary care providers may have a higher threshold than 140/90 mmHg for the diagnosis and treatment of hypertension, despite JNC7 guidelines [39]. Finally, young adults with intermittently normal blood pressures at baseline had a 26% slower diagnosis rate, emphasizing the need for out-of-office blood pressures to evaluate variability [40].

Predictors of receiving a hypertension diagnosis in the larger population were similar to findings observed among young adults. Provider age predicted a slower diagnosis rate for adults overall, but not when examining delays solely among young adults. Interestingly, there was an interaction between stage of hypertension and year of study entry, reflecting faster diagnosis rates for patients with Stage 2 hypertension during later study years. Although reasons for this interaction are likely multifactorial (e.g. healthcare system interventions), it represents a change in practice patterns over time [32]. However, this interaction was not significant among young adults, highlighting a continued gap in hypertension management between younger and older adult populations.

These critical findings underscore the need for healthcare system interventions tailored to young adults to improve the diagnosis of hypertension. Young adults were censored primarily due to no longer meeting criteria for being currently managed, reflecting well documented transitions in this population (insurance, college, etc.) [41]. Interventions such as decreased time between follow-up visits or outreach between visits may improve the care of young adults with elevated blood pressures. The negative health effects of chronically elevated blood pressure should be routinely communicated, especially among young adults with multiple cardiovascular risk factors [38].

We asked the institution's ambulatory quality improvement committee to comment on our results on why approximately 40% of young adults with hypertension remain undiagnosed over 4 years. The committee included primary care physicians and nurse practitioners from two different clinics and quality improvement administrative directors. Both physicians highlighted time as a major factor. According to one physician, 'it is not possible to address everything in a 15-min visit'. One quality director emphasized the need for a greater number of 'nurse blood pressure follow-up clinic visits'. Another physician shared the importance of 'following the guidelines' to direct appropriate follow-up for hypertension management and highlighted that 'each provider does things differently in their own clinic'. One nurse practitioner was concerned about 'trusting the blood pressure' if the blood pressure measurement technique varied between clinics. Even from this single committee, the need is demonstrated for system-level interventions to improve hypertension control among young adults.

A major strength of this study is the evaluation of a young adult patient population with incident hypertension that was receiving regular primary care within a large multispecialty group practice. A limitation is the potential for misclassification of hypertension and comorbidities using administrative data; however, previously established and published algorithms were utilized to help address this concern.

As lifestyle modification counseling is critical to hypertension management per JNC 7 guidelines [1], we are aware that some providers may have provided lifestyle counseling but did not code a hypertension diagnosis. However, we demonstrated through manual chart abstraction that 45% of the 500 randomly selected young adults did not have documented counseling. Although we were unable to capture verbal counseling provided during the encounter, we did capture all provider notes, written patient instructions, and handouts provided through the integrated electronic health record system. Previous research that used videotaped encounters to assess lifestyle counseling also demonstrated low lifestyle counseling rates [42].

Finally, our sample was limited to a single Midwestern healthcare system and predictors may differ among other populations, healthcare systems, and geographic regions. However, the healthcare system included in this study is one of the 10 largest physician practice groups in the United States, including over 300 primary care physicians and 43 primary care clinics. The primary care clinics are located in both urban and rural settings, span across multiple counties, and are owned and operated by various entities including a hospital, a multispecialty physician group, and an academic health center. In addition, the inclusion of patient demographic, comorbidity, and utilization data in addition to provider data from this heterogeneous group of clinics improves the generalizability and clinical applicability of our data.

In conclusion, young adults, even with regular primary care use, have a significantly slower rate of receiving an initial hypertension diagnosis than middle-aged and older adults. Multiple factors contribute to poor hypertension diagnosis rates among young adults. Primary care interventions, tailored to young adults, are needed to improve hypertension control rates.

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Conflicts of interest

H.J., C.B., N.P., and A.S. have clinical appointments with an academic group practice that has a financial interest in delivering care to the general population from which study

participants were drawn. For the remaining authors, no conflicts of interest were declared.

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Reviewers' Summary Evaluations

Reviewer 1

The strengths of the article are that this was a large data audit that identified a population group of young adults who could benefit from more proactive intervention to prevent cardiovascular disease and other complications from hypertension. Enhanced physician education and awareness of the need not only to monitor but control blood pressure by initiating antihypertensive therapy sooner is required to achieve optimal blood pressure control. The main weakness of the article is its retrospective design that can only provide evidence of associations between the factors investigated and earlier and later diagnosis of hypertension.

Reviewer 2

The paper by Johnson *et al.* reports the results of a study aimed at assessing the rate of initial hypertension diagnosis and factors that contribute to slower or faster rates of diagnosis in relation to different age's strata in a primary care setting. The authors found that young age, current smoking and white ethnicity were independent predictors of a slower hypertension diagnosis. On the whole, this finding indicates that the risk of cardiovascular complications due to hypertension is underestimated in young people. Despite some limitations, including a retrospective design and the use electronic health record data to define patients with hypertension and other comorbidities, this study supports the view that management of hypertension needs to be improved in young individuals.