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Blood pressure control among Veterans with high cardiovascular disease risk

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ABSTRACT

Objective: Blood pressure (BP) control reduces risk of cardiovascular disease (CVD), the major cause of disability and mortality among the nine million U.S. Veterans receiving care in Veterans Affairs (VA) medical centers. This study examined BP control, defined as a systolic BP < 130 mmHg and diastolic BP < 80 mmHg, among U.S. Veterans with hypertension at high risk for primary or secondary CVD events.

Methods: We utilized data from the VA Informatics and Computing Infrastructure Corporate Data Warehouse on primary care visits within the eight Great Lakes VA medical centers for Veterans with at least one visit between January 1, 2019, and February 28, 2020 and a documented visit within the 12 months prior to study initiation date. Analyses focused on Veterans with diagnosed hypertension and one or more of the following: age ≥65 years, and/or diagnosis of CVD, diabetes mellitus (DM) or chronic kidney disease (CKD). BP control was based on the last recorded BP measurement during the study period.

Results: The mean age of 83,633 Veterans with hypertension was 71.6 years (10.4) years, 96.4 % were male and race/ethnicity was reported as non-Hispanic White in 74.8 %, non-Hispanic Black or African American in 18.4 %, non-Hispanic Asian in 0.3 %, Alaskan Indian or Pacific Islander in 2.6 % and Hispanic in 2.5 %. Mean SBP and DBP based on vital signs at the last clinic visit were 130.8 mmHg (standard deviation [SD] 11.6) and 73.7 mmHg (SD 8.8), respectively. Overall, BP was controlled to < 130/80 mmHg in 38.7 % (95 % Confidence Interval [CI] 38.4, 39.1) and <140/90 mmHg in 76.9 % (95 % CI 76.7, 77.2). Among subgroups, BP was controlled to < 130/80 mmHg in 39.8 % (95 % CI 39.4, 40.2) of the Veterans aged ≥65 years, 45.3 % (95 % CI 44.7, 45.9) with CVD, 39.8 % (95 % CI 39.2, 40.3) with DM, 42.8 % (95 % CI 41.9, 43.6) with CKD and 47.1 % (95 % CI 45.5, 48.6) with CVD +DM +CKD. In contrast, BP control <140/90 mmHg was noted in over 75 % of Veterans within all subgroups.

Conclusion: In this group of Veterans with hypertension and high risk for CVD events, less than half had BP controlled to < 130/80 mmHg. Future studies should investigate strategies to improve BP control such as team-based care with home BP monitoring, education of clinicians on hypertension management, and increased utilization of automated office BP.

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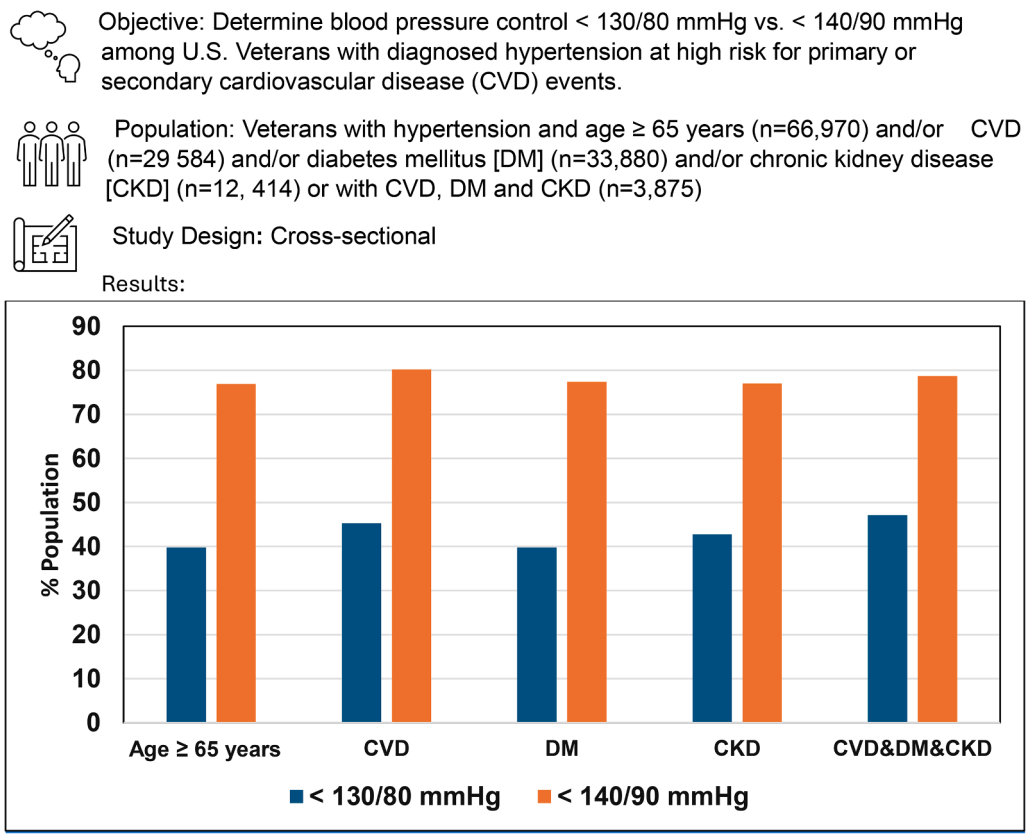

Central image: "Central illustration showing that less than half of U.S. Veterans with hypertension and high cardiovascular disease risk have blood pressure controlled to < 130/80 mmHg."

1. Introduction

High blood pressure (BP), a highly prevalent and modifiable risk factor for cardiovascular disease (CVD,) accounts for at least 30 % of CVD mortality in the U.S. [1]. While CVD mortality has declined over the past five decades, the rate of decline is slowing [2], and recent data suggests CVD mortality may even be increasing [3]. This plateau in CVD mortality has been attributed, in part, to lower rates of blood pressure (BP) control [4]. BP control is especially important for Veterans who receive care within the Veterans Affairs (VA) health system because CVD prevalence is approximately 40 % higher in this population compared to the general population [5] and CVD remains a major cause of mortality among Veterans [6]. Hypertension affects over 10 % of active duty service members [7] and almost 40 % of all Veterans [8]. Unique factors that can impact BP in Veterans include service-related injuries, chronic pain, and post-traumatic stress disorder [7,8]. From 2000 to 2010, the VA health system implemented multiple clinical interventions, including clinical reminders, decision support tools, and BP control performance measures across 15 VA medical centers to improve BP control. During this ten-year period, BP control, defined as a systolic BP (SBP) < 140 mmHg and diastolic BP (DBP) < 90 mmHg, increased from 51.5 % in 2000 to 74.1 % in 2010 [9]. Over the past decade, definitions of BP control have changed; both the American College of Cardiology/American Heart Association hypertension guideline [10] and the VA/Department of Defense (DoD) hypertension guideline [8] now recommend a SBP goal < 130 mmHg for adults with existing CVD or those with high CVD risk due to presence of diabetes mellitus (DM) or chronic kidney disease (CKD) in the absence of contraindications. Several current studies have shown that less than half of U.S. adults with both hypertension and high risk for primary or secondary CVD events, have BP controlled to < 130/80 mmHg [4,11–14].

The 2020 VA/DoD hypertension guideline [8] recommends a target SBP goal <130 mmHg for most Veterans with hypertension. Despite this recommendation, the percentage of Veterans with newly diagnosed hypertension treated to a SBP <130 mmHg declined from 51 % during 2016 to 45 % in 2021 [15]. We previously reported that less than 40 % of Veterans with high CVD risk who are receiving hypertension treatment in the Great Lakes VA Healthcare system medical centers during calendar year 2019 had SBP controlled to < 130 mmHg [16]. However, to our knowledge, no previous study has reported rates of BP control among Veterans with hypertension and CVD, DM or CKD. More knowledge on BP control and its associated factors within the VA healthcare system can inform quality improvement programs to improve BP control for Veterans. This study examined BP control, defined as a SBP < 130 mmHg and diastolic BP < 80 mmHg among Veterans with a hypertension diagnosis receiving care in clinics affiliated with eight Great Lakes VA medical centers and at least one high CVD risk factor, including age ≥ 65 years, CVD, DM, or CKD diagnosis.

2. Methods

2.1. Study population

The research was approved by the Edward Hines VA Hospital Institutional Review Board and the Edward Hines VA Hospital Research and Development Committee. At least one author had access to all data and is responsible for the study findings. The study examined data from Veterans aged 18 to 85 years receiving care in a VA patient aligned care team (PACT) clinic affiliated with the eight medical centers in the VA Great Lakes Health Care System (Veterans Integrated Services Network 12). These eight medical centers have a total of 41 outpatient PACT clinics that provide health care services to nearly 800,000 Veterans in

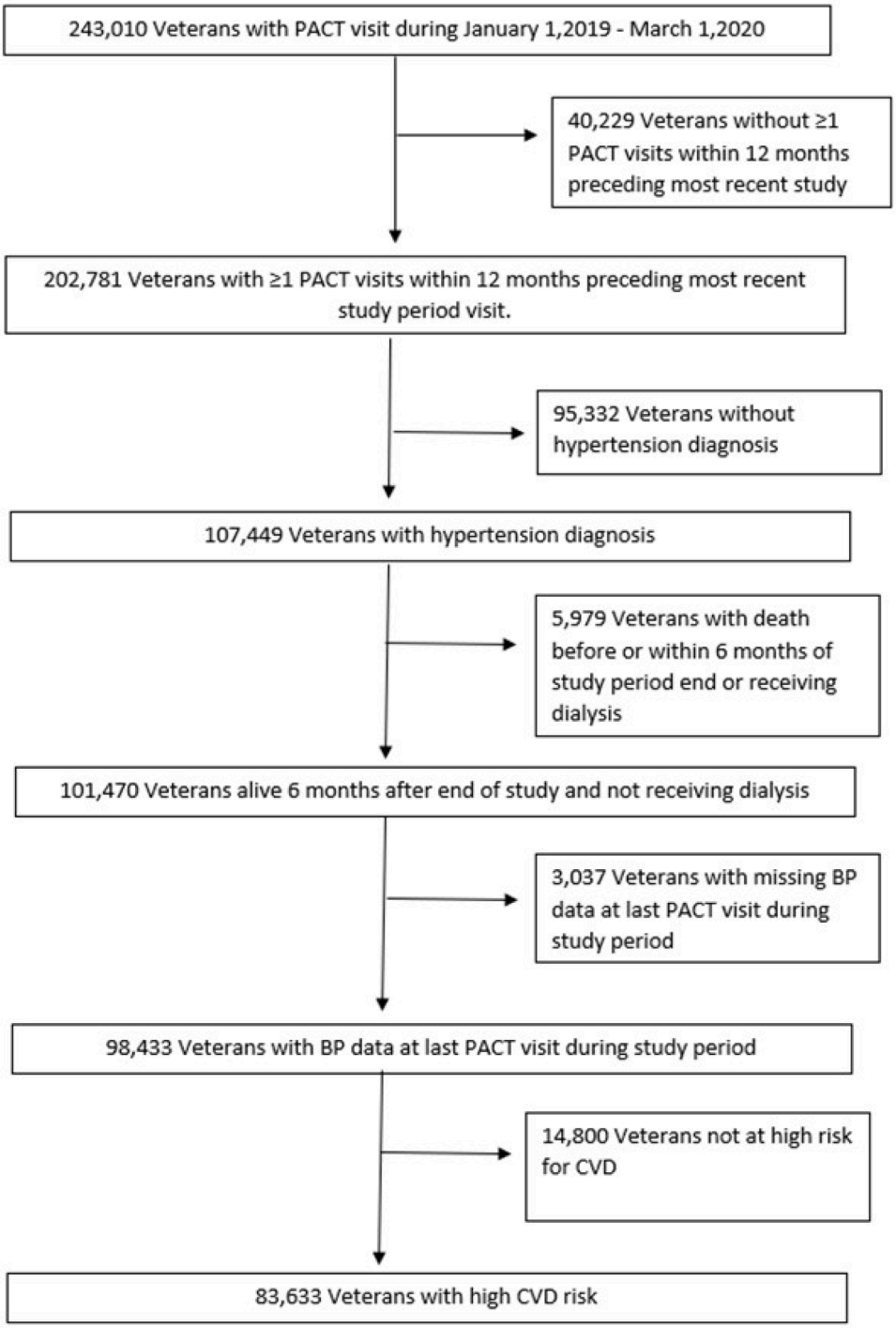

Fig. 1. Flowchart of selection of Veterans for analysis of blood pressure control.

four states (Illinois, Michigan Upper Peninsula, Wisconsin, and Northwest Indiana). Data were obtained from the VA's National Corporate Data Warehouse (CDW), which includes vital signs, patient demographics, outpatient encounter diagnosis, procedure codes (ICD10 and CPT codes), laboratory values, and co-morbidities. A total of 243,010 distinct Veterans who had visited a Great Lakes VA Healthcare system PACT clinic at least once between January 1, 2019, and February 28, 2020, were identified. Within this group, 202,781 Veterans had a documented PACT visit within the 12 months leading up to first PACT visit during the study period, and over half ($n = 107,449$) had either an ICD-10 code indicating hypertension or documentation of hypertension within the electronic health record (EHR) problem list.

We excluded Veterans who died either prior to or during the six months immediately following the first clinic visit occurring between Jan 1, 2019, and February 28, 2020 ($n = 4287$), were receiving dialysis ($n = 1692$), or who lacked recorded BP measurements on the last clinic visit during the study period ($n = 3037$). With these exclusions, a total of 98,433 Veterans with diagnosed hypertension had at least one PACT visit during the study period (Fig. 1). Our analyses examined BP control in Veterans with one or more of the following: age $\geq$ 65 years, history of CVD, DM or CKD. Among the 98,433 Veterans, 83,633 were either age $\geq$ 65 years and/or had one or more specified co-morbidities (Fig. 1).

2.2. Blood pressure control and medication classes

Methods for BP measurement in VA PACT clinics have been previously published [16]. BP was measured using semi-automated devices (Dinamap), and some, but not all, clinics used aneroid sphygmomanometers (auscultatory method) to confirm an elevated BP. Automated office BP (AOBP) [17], whereby BP is measured in one minute intervals using an automated device and the average of the three BP measurements are reported, was not often used to confirm an elevated BP. BP control was based on vital signs recorded during the last PACT visit during the study period and defined as a SBP < 130 mmHg and DBP < 80 mmHg. We also examined BP control defined as a SBP < 140 mmHg and DBP < 90 mmHg. Dispensed BP lowering medications were determined for the four-month period before the last clinic visit during the study period using the VA CDW outpatient Rxout datasets. The RxOut datasets contain product-level information about medications dispensed by VA pharmacies such as the product's National Drug Code number and VA drug class. Medication classes for BP lowering drugs were categorized as angiotensin-converting enzyme inhibitors or angiotensin-2 receptor blockers (ACEi/ARB), diuretics (thiazide, loop, and potassium sparing diuretics), beta-blockers, calcium channel blockers, alpha blockers, vasodilators, and central alpha agonists.

2.2.1. Demographics and co-morbidities

Data on demographics and co-morbidities were obtained from the CDW. Race and ethnicity were based on self-report documented in the EHR. CVD was defined as a history of one or more of the following diseases based on International Classifications of Diseases, tenth revision (ICD-10) diagnosis codes or inclusion in the EHR problem list: arrythmia, coronary artery disease, heart failure, valvular heart disease, ischemic or hemorrhagic stroke, peripheral arterial disease, carotid artery disease or aortic aneurysm. Non-dialysis dependent CKD was defined as an ICD10 CKD diagnosis code and/or inclusion of CKD in the problem list. Presence of DM was based on ICD-10 codes or inclusion of type 1 or type 2 DM in the problem list.

Table 1
Baseline characteristics of the Veterans with hypertension by blood pressure control based on vital signs at the last clinic visit.

	[a]Total (*n* = 83,633)	< 130/80 mmHg (*n* = 32,398)	≥ 130/80 mmHg (*n* = 51,235)	< 140/90 mmHg (*n* = 64,252)	≥ 140/90 mmHg (*n* = 19,381)
[b]**Mean age, years**	71.6 (10.4)	72.3 (10.1)	71.7 (10.5) [c]	71.5 (10.3)	71.9 (10.6) [c]
Age Group					
< 65 years, %	19.9	17.7	21.3**	19.5	20.2 [c]
65–75 years, %	48.5	48.7	48.4	49.0	46.9
>75 years, %	31.6	33.6	30.3	31.2	32.9
Male, %	96.4	96.5	96.2 [c]	97.3	99.1 [c]
Race/Ethnicity					
Non-Hispanic Black/African American, %	18.4	16.0	20.0 [c]	17.4	21.8 [c]
Non-Hispanic White, %	74.8	77.2	73.3	75.9	71.4
Non-Hispanic Asian, %	0.3	0.3	0.3	0.3	0.3
Alaskan Indian/ Pacific Islander, %	2.6	2.6	2.6	2.6	2.6
Hispanic, %	2.5	2.3	2.6	2.5	2.5
Missing, %	1.4	1.5	1.3	1.4	1.5
BMI ≥30 kg/ m^2, %	48.4	47.8	48.7 [d]	48.9	46.6 [c]
Systolic BP, mmHg	130.8 (11.6)	116.8 (9.2)	139.7 (13.1)[c]	124.5 (10.9)	152.0 (12.7) [c]
Diastolic BP, mmHg	73.7 (8.8)	67.2 (7.5)	78.0 (9.7)[c]	71.6 (8.8)	81.1 (10.4) [c]
CVD, %	35.4	41.3	31.6 [c]	36.9	30.3 [c]
DM, %	40.5	41.6	39.8 [c]	40.8	39.4 [d]
CKD, %	14.8	16.3	13.9 [c]	14.8	14.7

[a] Veterans with hypertension diagnosis and age ≥ 65 years, and/or had cardiovascular disease, diabetes mellitus or chronic kidney disease.
[b] Data shown as mean (standard deviation).
[c] $P < 0.001$ and.
[d] < 0.05 for comparison to < 130/80 mmHg for column ≥ 130/80 mmHg and to < 140/90 mmHg for column ≥ 140/90 mmHg. For age group and race, the P value corresponds to the overall chi-square. BMI = body mass index; CVD = cardiovascular disease; DM = type 1 or type 2 diabetes mellitus; CKD = chronic kidney disease.

2.3. Statistical analysis

Characteristics of the cohort were examined overall and by BP control. Categorical variables were compared using a Chi-square test and continuous variables were compared using an unpaired *t*-test. BP control was examined by CVD risk subgroups. Logistic regression models were used to determine the odds of BP control while adjusting for demographics, and co-morbidities. Marginal effects were then used to calculate unadjusted and adjusted prevalence and 95 % confidence interval (CI) of BP control overall and by demographic factors and CVD risk subgroups. Due to the limited amount of missing data (race/ethnicity missing in 1.4 %), analyses were conducted using complete data only. All analyses were conducted using STATA v. 17.

3. Results

The mean age of 83,633 Veterans receiving care in one of eight Great Lakes VA Healthcare system medical centers was 71.6 years (10.4) years. Almost all (96.4 %) were male and race/ethnicity was self-reported as non-Hispanic White in 74.8 %, non-Hispanic Black or African American in 18.4 %, non-Hispanic Asian in 0.3 %, Alaskan Indian or Pacific Islander in 2.6 % and Hispanic in 2.5 % (Table 1). Mean SBP and DBP based on vital signs at the last PACT visit during the study period were 130.8 mmHg (standard deviation [SD] 11.6) and 73.7 mmHg (SD 8.8), respectively. Presence of CVD, DM, and CKD was 35.4 %, 40.5 % and 14.8 %, respectively. Overall, BP was controlled to < 130/80 mmHg in 38.7 % (95 % CI 38.4, 39.1) and < 140/90 mmHg in 76.9 % (95 % CI 76.7, 77.2). The mean number of dispensed BP lowering medication classes was 1.5 (SD 1.3) and less than half (45.7 %) were dispensed two or more BP lowering medication classes.

Mean age was higher among Veterans with BP < 130/80 mmHg vs. ≥ 130/80 mmHg (72.3 [SD10.1] vs. 71.7 (10.5); $P < 0.001$) (Table 1). Veterans with BP < 130/80 mmHg vs. ≥ 130/80 mmHg were less likely to self-report race/ethnicity as non-Hispanic Black/African American (16.0 % vs. 20.0 %) and more likely to report non-Hispanic White race (77.2 vs. 73.3). For those with BP control < 130/80 mmHg, mean values were 116.8 (SD 9.2) and 67.2 (SD 7.5), for SBP and DBP, respectively, while for BP < 140/90 mmHg, mean values were 124.5 mmHg (10.9) and 71.6 mmHg (8.8), for SBP and DBP respectively. Presence of CVD, DM and CKD were also higher among Veterans with BP < 130/80 mmHg vs. ≥ 130/80 mmHg. The mean number of dispensed BP medication classes generally did not differ by BP control and were 1.6 (1.4) and 1.5 (SD 1.3) among Veterans with BP < 130/80 mmHg and < 140/90 mmHg, respectively (Table 1). BP control defined as < 130/80 mmHg was noted in 39.8 % (95 % CI 39.4, 40.2) of the Veterans aged ≥ 65 years, 45.3 % (95 % CI 44.7, 45.9) with CVD, 39.8 % (95 % CI 39.2, 40.3) with DM and 42.8 % (95 % CI 41.9, 43.6) with CKD. In contrast, BP control < 140/90 mmHg was noted in over 75 % of Veterans within all subgroups (Table 4 and Fig. 2). Across all subgroups with BP levels ≥ 130/80 mmHg and ≥ 140/90 mmHg, mean SBP was approximately 140 mmHg and 150 mmHg, respectively.

Table 2 shows the unadjusted and adjusted prevalence of BP control defined as < 130/80 mmHg and < 140/90 mmHg. Both unadjusted and adjusted prevalence of BP control defined as either < 130/80 mmHg or as < 140/90 differed by race/ethnicity and was lowest in Veterans who

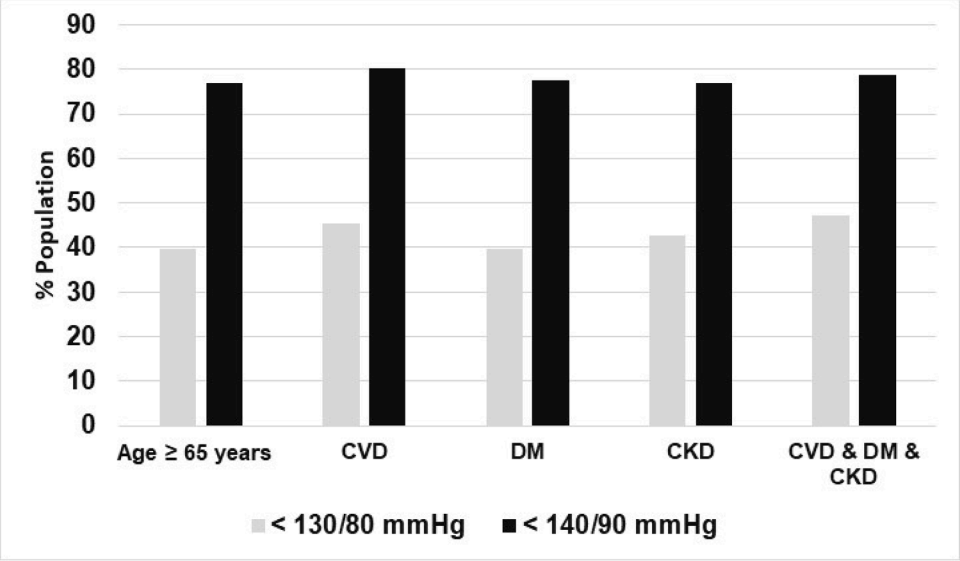

Fig. 2. Blood pressure control by age ≥65 years and by presence of co-morbidities among 83, 633 Veterans with hypertension by BP control < 130/80 mmHg and by < 140/90 mmHg based on vital signs during the last clinic visit during the follow-up period. CVD = Cardiovascular Disease; DM = Diabetes Mellitus; CKD = Chronic Kidney Disease.

reported non-Hispanic Black or African American race/ethnicity. Prevalence of BP control < 130/80 mmHg was highest in those with CVD + DM + CKD at 46.7 % (95 % CI 45.0, 48.3) and these Veterans had the highest mean number of dispensed BP lowering drug classes, with an average of 2.4 (SD 1.5) (Table 3). Mean number of dispensed BP lowering drug classes did not differ by BP control status in all subgroups (Table 3). Table 4 shows mean SBP, DBP, and number of dispensed BP lowering medication classes stratified by age ≥ 65 years, co-morbidity status, and BP control.

Fig. 3 shows the dispensed BP lowering medication classes by BP control status defined as < 130 mmHg and < 140/90 mmHg. The most commonly dispensed BP lowering medication classes were ACEi/ARB and beta-blockers. Diuretics were dispensed for approximately 30–40 % for all subgroups while CCB were dispensed less frequently than other medications across all subgroups. Diuretics were prescribed at similar rates 36.0 % and 36.9 % with BP control defined as < 130/80 mmHg and < 140/90 mmHg, respectively. Similar findings were noted after stratifying Veterans by co-morbidity status and by BP control (Fig. 4). Beta blockers were most frequently dispensed for Veterans with CVD (70.5 %) and were more frequently dispensed in this group than ACEi/ARB (Fig. 4).

4. Discussion

Our findings, as well as a recent report among U.S. Veterans [15], suggests that over 75 % of Veterans with hypertension have BP controlled to < 140/90 mmHg, and this level of BP control is substantially higher than rates reported in the general U.S. population [13,18]. In the 2022 National Committee of Quality Assurance report of BP control < 140/90 mmHg among adults age 18–85 years with a hypertension diagnosis, BP control ranged from 54.9 % among adults with commercial preferred provider organization insurance to 72.9 % among adults with Medicare health maintenance organizations insurance [19]. However, this study may be one of the first studies to demonstrate that less than half of Veterans with hypertension and high CVD risk have BP controlled to <130/80 mmHg. These findings are similar to studies in the general U.S. population [12], which show that less than half of U.S. adults age ≥ 65 years [20] and those with CVD [4], DM [11] or CKD [14] have BP controlled to < 130/80 mmHg. While guidelines recommend a BP goal < 130/80 mmHg for most Veterans [8], clinical reminders and quality measures for BP control continue to focus on a BP goal < 140/90 mmHg [16]. BP control can be improved with implementation of quality improvement programs that are adapted for VA PACTs. Quality improvement programs can increase BP control through improving BP measurement with use of AOBP, increasing use of team-based care for hypertension management, helping clinicians identify optimal BP goals and educating clinicians and Veterans.

In our study, we found racial/ethnic differences in BP control, specifically lower prevalence of BP control defined as either < 130/80 mmHg or as < 140/90 mmHg among Veterans who reported Non-Hispanic Black or African American or Hispanic race/ethnicity compared to other racial/ethnic groups. These findings are consistent with lower BP control among Non-Hispanic Black or African American and Hispanic adults compared with Non-Hispanic White adults in the general U.S. population, but these racial/ethnic disparities appear to be decreasing [13]. The findings of racial/ethnic differences in BP control in VA clinics emphasize the need for interventions to improve hypertension management and reduce health disparities in BP control.

Less than half of Veterans with high risk for CVD mortality were dispensed two or more BP lowering medication classes. In clinical trials, an average of one additional BP lowering medication is required to obtain a SBP target goal of < 130 mmHg compared to < 140 mmHg [21–24]. Reasons for lack of differences in mean number of BP lowering drug classes by BP control groups in this cohort may include misclassification of BP control due to measurement errors [16,17,25], and/or issues with medication adherence. We have previously reported a lack of consistent BP measurement protocols across the eight medical centers within the Great Lakes VA Healthcare System [16] and low use of AOBP [17]. Use of AOBP improves accuracy of clinic BP measurement and shows a higher correlation with average daytime ambulatory BP measurement [17]. Currently, elevated clinic BP measurements using automated devices are often confirmed using auscultatory methods and not AOBP [16]. Standardized protocols for BP measurement and utilization of AOBP to confirm elevated BP will provide more accurate assessment of BP control rates within VA PACT clinics. Use of AOBP to confirm elevated BP measurements may also increase clinician confidence in BP measurement accuracy and lower therapeutic inertia. Audit and feedback of BP control to clinicians and utilization of team-based care with nurses and pharmacists can also improve BP control.

In this group of Veterans with hypertension and high risk for CVD

Table 2
Unadjusted and adjusted prevalence of blood pressure control by demographic characteristics and presence of comorbidities.

	Unadjusted Prevalence BP Control < 130/80 mmHg (95 % CI)	*Adjusted Prevalence BP Control < 130/80 mmHg (95 % CI)	Unadjusted Prevalence BP Control < 140/90 mmHg (95 % CI)	*Adjusted Prevalence BP Control < 140/90 mmHg (95 % CI)
Age ≥ 65	39.8 (39.4, 40.2)	39.9 (39.5, 40.3)	76.9 (76.6, 77.2)	77.1 (76.7, 77.4)
Male	38.8 (38.5, 39.2)	38.9 (38.5, 39.2)	77.0 (76.7, 77.3)	77.1 (76.8, 77.5)
Race/ Ethnicity+				
Non-Hispanic White	39.9(39.5, 40.3)	40.0 (39.7, 40.5)	78.0 (77.7, 78.3)	78.2 (77.8, 78.5)
Non-Hispanic Black or African American	33.6 (32.9, 34.4)	33.7 (33.0, 34.5)	72.7 (72.0, 73.4)	72.9 (72.1, 73.6)
Non-Hispanic Asian	39.9 (38.3, 41.4)	42.4 (36.3, 48.5)	78.2 (73.2, 83.2)	79.0 (74.0, 84.0)
Non-Hispanic Native American, Hawaiian, Pacific Islander	40.0 (38.3, 41.4)	38.8 (36.9, 40.7)	76.7 (75.4, 78.1)	77.1 (75.6, 78.8)
Hispanic	36.3 (34.2, 38.4)	36.5 (34.4, 38.6)	76.7 (74.9, 78.6)	76.9 (75.0, 78.8)
Co-morbidities				
Cardiovascular Disease+	45.3 (44.7, 45.9)	45.3 (44.7, 45.9)	80.1 (79.7, 80.6)	80.2 (79.7, 80.6)
Diabetes Mellitus	39.8 (39.2, 40.3)	38.5 (39.3, 40.4)	77.4 (77.0, 77.9)	77.5 (77.0, 78.0)
Chronic Kidney Disease	42.8 (41.9, 43.6)	42.7 (41.8, 43.6)	77.0 (76.3, 77.8)	76.9 (76.2, 77.7)
Cardiovascular Disease & Diabetes Mellitus & Chronic Kidney Disease	47.1 (45.5, 48.6)	46.7 (45.0, 48.3)	78.7 (77.4, 80.0)	78.3 (76.9, 79.6)

[a]Adjusted for age, sex, race, ethnicity, body mass index, and presence of diagnosed cardiovascular disease, diabetes mellitus, and chronic kidney disease.
[b]P<0.001 in fully adjusted logistic regression model with BP control as dependent variable.

Table 3
Blood pressure control and mean blood pressure values based on vital signs at the last clinic visit by age group ≥65 years and by co-morbidities.

	Age ≥ 65 years (*n* = 66, 970)	CVD (*n* = 29,584)	DM (*n* = 33,880)	CKD (*n* = 12,414)	CVD & DM & CKD (*n* = 3875)
SBP < 130/80 mmHg, %	39.8	45.3	39.8	42.8	47.1
SBP < 140/90 mmHg, %	76.9	80.2	77.4	77	78.7
[a]**Mean SBP, mmHg**	131.0 (11.5)	128.5 (11.6)	130.9 (11.3)	130.0 (12.0)	130.2 (11.3)
[a]**Mean DBP, mmHg**	72.7 (8.6)	66.3 (7.7)	73.1 (8.9)	72.2 (9.3)	73.7 (8.0)
[a]**Mean # BP lowering medication classes**	1.5 (1.2)	1.9 (1.4)	1.8 (1.4)	2.0 (1.4)	2.4 (1.5)
≥2 BP lowering medication class, %	47.2	59.1	54.6	61.1	72.5

[a] Data shown as mean (standard deviation); SBP = systolic blood pressure; DBP = diastolic blood pressure; BP = blood pressure; CVD = cardiovascular disease; DM = diabetes mellitus; CKD = chronic kidney disease.

Table 4
Mean systolic and diastolic blood pressure and mean number of blood pressure lowering medication classes by age ≥65 years, presence of co-morbidities and blood pressure control based on vital signs at the last clinic visit.

	Age ≥ 65 years (*n* = 66,970)			
	BP < 130/ 80 mmHg (*n* = 26,655)	BP ≥ 130/ 80 mmHg (*n* = 40,315)	BP < 140/ 90 mmHg (*n* = 51,515)	≥ 140/90 mmHg (*n* = 15,455)
SBP, mmHg	116.9 (9.2)	140.4 (13.0)	124.6 (10.9)	152.5 (12.6)
DBP, mmHg	66.6 (7.5)	76.6 (9.4)	70.6 (8.9)	79.5 (10.5)
# BP lowering medication classes	1.6 (1.4)	(1.3)	1.5 (1.3)	1.5 (1.3)
	Cardiovascular Disease (*n* = 29, 584)			
	BP < 130/ 80 mmHg (*n* = 13,400)	BP ≥ 130/80 mmHg (*n* = 16,184)	BP < 140/90 mmHg (*n* = 23,711)	BP ≥ 140/ 90 mmHg (*n* = 5873)
SBP, mmHg	115.5 (7.7)	139.3 (13.1)	122.7 (11.6)	151.8 (13.0)
DBP, mmHg	66.3 (7.7)	77.2 (9.9)	70.3 (9.2)	80.2 (11.4)
# BP lowering medication classes	1.9 (1.4)	1.9 (1.4)	1.9 (1.4)	1.9 (1.4)
	Diabetes Mellitus (*n* = 33, 880)			
	BP < 130/80 mmHg (*n* = 13,470)	BP ≥ 130/ 80 mmHg (*n* = 20,410)	BP < 140/ 90 mmHg (*n* = 26,234)	BP ≥ 140/ 90 mmHg (*n* = 7646)
SBP, mmHg	116.9 (9.1)	139.9 (12.8)	124.5 (10.9)	152.0 (12.5)
DBP, mmHg	66.9 (7.7)	77.2 (9.7)	71.0 (9.1)	80.3 (11.0)
# BP lowering medication classes	1.8 (1.4)	1.8 (1.4)	1.8 (1.4)	1.9 (1.4)
	Chronic Kidney Disease (*n* = 12, 414)			
	BP < 130/ 80 mmHg (*n* = 5307)	BP ≥ 130/80 mmHg (*n* = 7107)	BP < 140/ 90 mmHg (*n* = 9561)	BP ≥ 140/90 mmHg (*n* = 5873)
SBP, mmHg	115.8 (9.9)	140.4 (13.6)	123.2 (11.6)	151.9 (12.6)
DBP, mmHg	66.1 (7.8)	76.9 (10.4)	70.1 (9.3)	79.6 (12.1)
# BP lowering medication classes	2.0 (1.5)	2.0 (1.4)	2.0 (1.4)	2.1 (1.5)
	Cardiovascular Disease & Diabetes Mellitus & Chronic Kidney Disease (*n* = 3875)			
	BP < 130/ 80 mmHg (*n* = 1824)	BP ≥ 130/80 mmHg (*n* = 2051)	BP < 140/90 mmHg (*n* = 3048)	BP ≥ 140/90 mmHg (*n* = 827)
SBP, mmHg	115.0 (10.2)	140.9 (13.9)	122.1 (12.2)	149.0 (13.9)
DBP, mmHg	64.9 (8.0)	75.1 (10.3)	68.0 (9.3)	77.0 (11.8)
# BP lowering medication classes	2.4 (1.5)	2.5 (1.5)	2.4 (1.5)	2.6 (1.5)

Data shown as mean (standard deviation); BP = blood pressure; SBP = systolic blood pressure; DBP = diastolic blood pressure.

mortality, we observed that beta-blockers were the second most commonly dispensed BP lowering medication class. Beta-blockers are recommended primarily for coronary artery disease, post-myocardial infarction, heart failure, and some arrhythmias and are not considered first line choice for BP lowering in the absence of a clinical indication

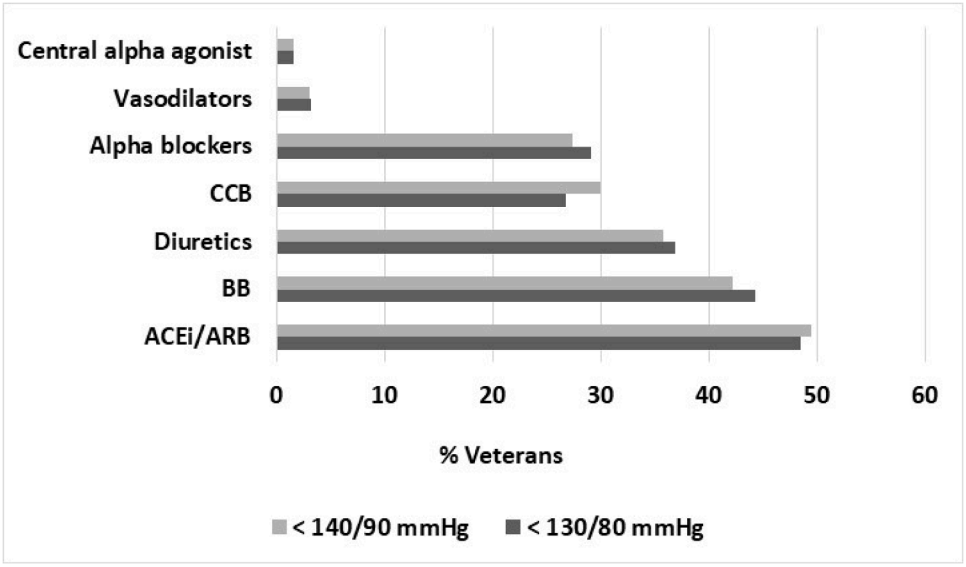

Fig. 3. Dispensed blood pressure lowering medication classes during the four months prior to the last clinic visit among Veterans with hypertension by blood pressure control < 130/80 mmHg and by < 140/90 mmHg. CCB = calcium channel blockers; Diuretics include thiazide, loop and potassium sparing diuretics; BB = beta blockers. ACEi/ARB = angiotensin converting enzyme inhibitors/angiotensin receptor blockers.

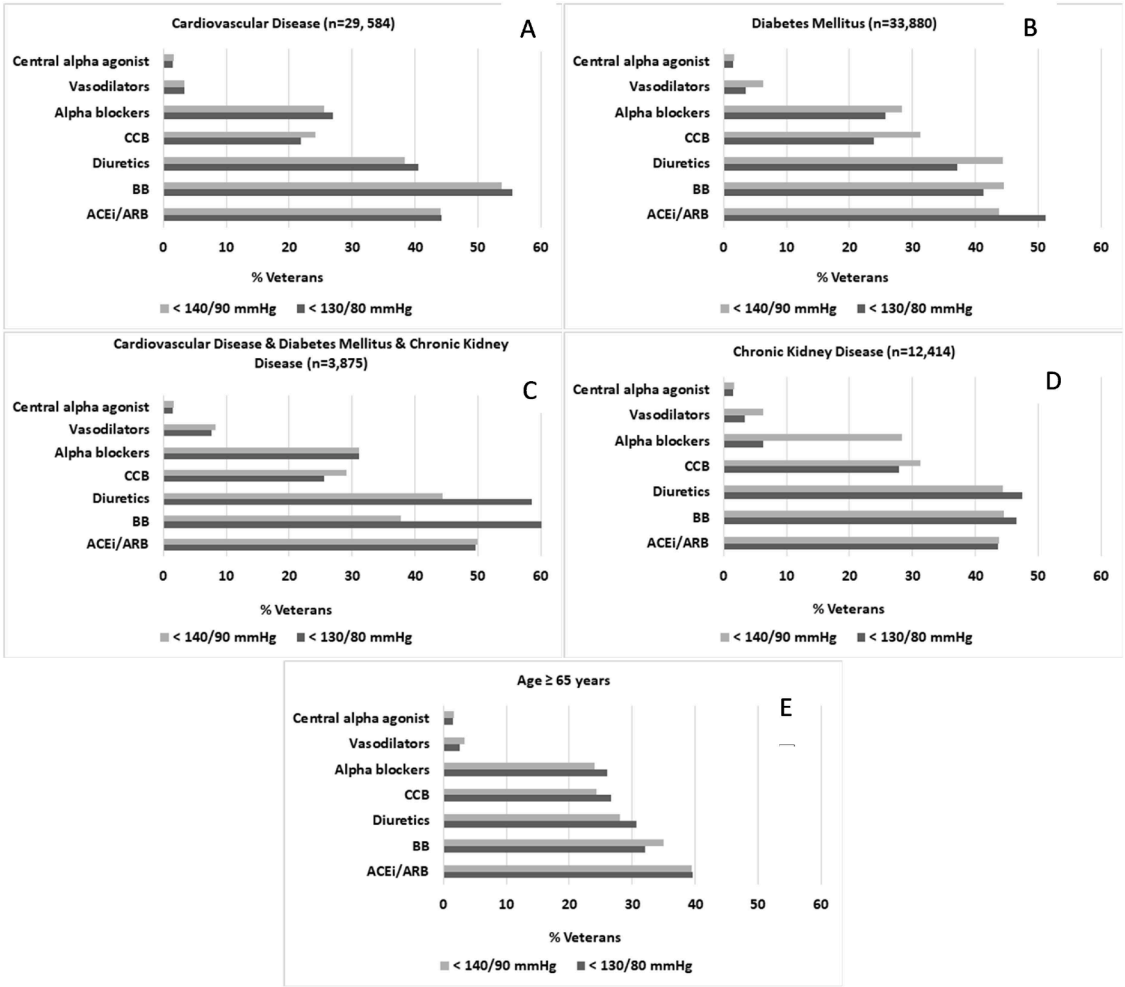

Fig. 4. Dispensed blood pressure lowering medication classes during the four months prior to the last clinic visit by age ≥ 65 years and co-morbidities and blood pressure control < 130/80 mmHg and < 140/90 mmHg. A = Cardiovascular Disease; *B*= Diabetes Mellitus; C = Cardiovascular Disease & Diabetes Mellitus & Chronic Kidney Disease; D = Chronic Kidney Disease); *E* = Age ≥ 65 years Central Illustration for analysis of blood pressure control in Veterans with high cardiovascular risk.

[8]. Several large trials have demonstrated that beta-blockers do not provide the same level of risk reduction for stroke, CVD events, and mortality [26,27] as compared to other BP lowering medication classes such as diuretics. Beta-blockers lower peripheral systolic BP more than central systolic BP [26], but these discrepancies are more pronounced with non-vasodilating vs. vasodilating beta-blockers [28]. The VA/DoD 2020 hypertension guideline [8] recommends use of ACEi/ARB, diuretics and CCBs as first line treatment for BP control and states that thiazide diuretics should be used in Veterans aged ≥ 65 years to reduce risk of CVD outcomes. While we lacked information on the indication for a dispensed medication class, our data suggest potential opportunities for more frequent use of first-line antihypertensive therapies more broadly. More education of treating clinicians on hypertension management and team-based care could potentially improve BP control in VA PACT clinics [29].

Our study has limitations related to BP measurement processes and additional contextual data about dispensed medications. First, BP measurements taken during PACT visits may have errors due to noisy clinic environments where vital signs are taken, lack of an appropriate rest period, incorrect cuff size, or digit bias due to use of auscultatory BP measurement methods [16]. Second, Veterans may not take their BP lowering medication on the days of clinic visits and we lacked information on home BP measurements, medication compliance or doses. Medication class data was based on dispensed medications during a four-month period prior to the last clinic visit during the study period. Within the VA health system, medications are usually mailed directly to the Veteran's home and fills for existing medications are not dispensed unless requested by the patient or clinician. The cohort of Veterans was older and we lacked information on dementia, or frailty which could influence clinician management of hypertension due to concerns for falls. To address the issue of severe illness and frailty, we excluded Veterans who died during the first six months of the study follow-up period. Our analyses focused on data from the Great Lakes Healthcare System and may not reflect the care delivered within other areas of the VA health system.

In summary, our analyses suggest that less than half of Veterans with hypertension and high risk for CVD have BP controlled to < 130/80 mmHg. We also noted racial/ethnic differences in BP control. Beta-blockers, which are not considered first-line therapy for hypertension, were the second most frequent class of dispensed BP lowering medication classes. These results underline the need for more effective strategies to improve BP control and reduce health disparities. Future studies should explore the implementation of quality improvement programs to increase BP control and reduce health disparities in Veterans with high CVD risk, and these strategies could include increased utilization of AOBP for more accurate BP measurement, education of clinicians on hypertension management including first line medications and addition of a second medication if patient is not controlled, and team-based care with home BP monitoring.

Glossary

VA = Veterans Affairs
BP = Blood Pressure
SBP = Systolic Blood Pressure
DBP = Diastolic Blood Pressure
BMI = Body Mass Index
CVD = Cardiovascular Disease
DM= Diabetes Mellitus
CKD = Chronic Kidney Disease
PACT = Patient Aligned Clinic Team
CDW = Corporate Data Warehouse
EHR = Electronic Health Record
ICD-10 = International Classifications of Diseases, tenth revision
AOBP=Automated Office Blood Pressure
SD= Standard Deviation
ACEi/ARB = Angiotensin Converting Enzyme Inhibitors/Angiotensin Receptor Blockers
BB = Beta-blockers
CCB= Calcium Channel Blockers

Author agreement

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Dr. Kramer has been an educational consultant for Bayer pharmaceuticals and Vifor pharmaceuticals. All other authors have no conflicts of interest to declare.

Data statement

Data are available through the Veterans Affairs Corporate Data Warehouse with a Veterans Affairs Institutional Review Board approval.

CRediT authorship contribution statement

Aseel Zghayer: Writing – review & editing, Writing – original draft. **Meghan O'Halloran:** Writing – review & editing, Writing – original draft, Funding acquisition, Conceptualization. **Kevin Stroupe:** Writing – review & editing, Methodology, Funding acquisition, Formal analysis. **Zhiping Huo:** Writing – review & editing, Formal analysis, Data curation. **Frances Weaver:** Writing – review & editing, Funding acquisition. **Ashley Hughes:** Writing – review & editing, Funding acquisition. **Talar Markossian:** Writing – review & editing. **Raveen Neddy:** Writing – review & editing. **Holly Kramer:** Writing – review & editing, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Meghan O'Halloran reports financial support was provided by US Department of Veterans Affairs. Meghan O'Halloran reports financial support was provided by VHA Health Services Research & Development. Meghan O'Halloran, Holly Kramer, Kevin Stroupe, Fran Weaver, Ashley Hughes reports a relationship with US Department of Veterans Affairs that includes: employment. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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