Original Article

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Severe hypertension in China: results from the China PEACE million persons project

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Introduction: People with severe hypertension have high risk of target organ damage, yet few studies focus specifically on this population. We sought to assess the characteristics, prevalence, awareness, and treatment patterns of severe hypertension among middle-aged adults in China.

Methods: We enrolled 2 660 666 participants aged 35–75 years from 31 provinces between 2014 and 2018 in the cross-sectional China Patient-Centered Evaluative Assessment of Cardiac Events Million Persons Project. Severe hypertension was defined as SBP of at least 160 mmHg or DBP of at least 100 mmHg. Awareness and treatment were defined as self-reported diagnosis of hypertension and current use of antihypertensive medication, respectively. Analyses were completed in 2019.

Results: Our sample included 2 618 757 adults with a mean age of 55.6 years (SD 9.8), 59.6% of whom were women. A total of 378 457 (14.5%) participants had severe hypertension, of whom 222 533 (58.8%) were untreated. The age–sex-standardized rate of severe hypertension was 11.6% based on the 2010 Chinese Census data. Advanced age, female sex, current drinking, obesity, lower income, diabetes, and prior cardiovascular events were associated with higher risk of severe hypertension (all $P < 0.01$). Of untreated participants with severe hypertension, only 60 484 (27.1%) were aware of their conditions. Among participants with severe hypertension despite treatment, 84.7% reported taking one class of antihypertensive medication; only 15% reported taking guideline-recommended combination therapy.

Conclusion: Many millions of people in China have severe hypertension and the vast majority are unaware of their condition and undertreated. There are immense opportunities to improve outcomes in this high-risk group.

Keywords: awareness, cardiovascular disease prevention, prevalence, severe hypertension, treatment

Abbreviations: ACEI, angiotensin-converting-enzyme inhibitor; ARB, angiotensin-receptor blocker; CCB, calcium channel blocker; CI, confidence interval; CVD, cardiovascular disease; PEACE, Patient-Centered Evaluative Assessment of Cardiac Events; SD, standard deviation; TCM, traditional Chinese medicine

INTRODUCTION

People with severe hypertension (SBP ≥ 160 mmHg or DBP ≥ 100 mmHg) should be a public health priority, yet few studies focus specifically on this population [1]. In China, hypertension affects 1 in 4 adults, of whom 40% have severe hypertension [2]. A better understanding of people with severe hypertension, who are at particularly high risk of the sequelae of hypertension, may help target public health interventions and raise awareness of how to prioritize efforts.

A large number of studies have assessed the characteristics, prevalence, and treatment of hypertension in China [2–6] but data on those with severe hypertension are limited. We have previously reported that about one in eight adults aged 35–75 years in China have severe hypertension but we did not investigate this high priority population in depth [6]. Previous studies commonly lacked a large enough sample size to fully capture the range of attributes of individuals with severe hypertension across diverse population subgroups. In addition, among people with severe hypertension who were untreated, it is unclear what proportion are unaware of their conditions. Among people with severe hypertension despite treatment, it is unclear whether the majority are inadequately treated or whether they have resistant hypertension (defined as blood pressure that remains above the target level despite concurrent use of three antihypertensive agents of different classes) [1,7,8]. This information is critical to inform policies and develop interventions to mitigate the harmful effect of hypertension.

Accordingly, we utilized data of 2.6 million people from the China PEACE (Patient-Centered Evaluative Assessment of Cardiac Events)-Million Persons Project, a government-

funded, large-scale population-based screening project in China, to conduct an in-depth analysis of severe hypertension. We sought to assess the characteristics, prevalence, awareness, and treatment patterns of severe hypertension among middle-aged adults in China.

METHODS

Participants and study design

The China-PEACE Million Persons Project methodology has been previously described [6,9]. From September 2014 to November 2018, we used a purposive sampling strategy to select 189 sites (114 rural counties, 75 urban districts) from all 31 provinces in mainland China. Sites were selected purposefully to reflect the diversity in geographic distribution, economic development, and population structure across the country. People were encouraged to participate in the project through publicity campaigns in the newspaper and on television. Of the 2 660 666 participants aged 35–75 years enrolled at these sites, we excluded 16 118 participants because of missing or extreme blood pressure values (SBP < 70 mmHg or >270 mmHg; DBP < 30 mmHg or >150 mmHg), and 25 791 participants because of missing data on covariates, including age, sex, education, household income, and BMI (Supplemental Figure S1, http://links.lww.com/HJH/B477). The central ethics committee at the China National Center for Cardiovascular Disease and the Institutional Review Board at Yale University approved this project. All enrolled participants provided written informed consent.

Data collection and variables

All participants had two blood pressure measurements in the right upper arm after 5 min of rest in a seated position by trained staff using an electronic blood pressure monitor (Omron HEM-7430; Omron Corporation, Kyoto, Japan) following standard protocol [9]. Similar types of blood pressure monitors have been validated in previous studies [10,11]. The values of both the readings as well as their mean were recorded. If the difference between the two measurements was greater than 10 mmHg, a third blood pressure reading was taken and the mean was calculated using the last two readings in such cases. Additionally, participants were asked if they had taken any prescription drugs for antiplatelet, blood pressure, lipid, or glucose control in the past 2 weeks during the in-person interview. Any participant who answered 'yes' to the question was asked specific prescription information including the drug name, dosage, and frequency. Those who did not remember the exact dosage identified the number of tablets or pills taken.

In accordance with the Chinese guideline [12], hypertension was defined as mean SBP at least 140 mmHg or mean DBP at least 90 mmHg or self-reported usage of an antihypertensive drug in the past 2 weeks. Severe hypertension (i.e. stage 2 and above hypertension) was defined as mean SBP at least 160 mmHg or mean DBP at least 100 mmHg. Less severe hypertension (i.e. stage 1 hypertension) was defined as mean SBP between 140 and 160 mmHg or mean DBP between 90 and 100 mmHg. Participants who did not have a history of hypertension

or antihypertensive medication use and who had a mean SBP less than 140 mmHg and a mean DBP less than 90 mmHg were defined as normotensive. Participants were considered to be aware of their hypertension if they responded 'yes' to the question 'have you ever been diagnosed with hypertension?' Participants were considered to be receiving treatment for hypertension if they reported using antihypertensive medication (Western or traditional Chinese medications) currently or within the last 2 weeks.

Information regarding participants' sociodemographic status (education, occupation, marital status, annual household income, and medical insurance), lifestyle (current smoking and current drinking), and medical history were collected during standardized in-person interviews conducted by trained research staff. We also measured height and weight using standard protocols. BMI was calculated as weight in kilograms divided by the square of height in meters. We defined obesity as BMI at least 28kg/m^2 in accordance with the recommendations of the Working Group on Obesity in China [13]. We defined current drinker as participants who drink at least one time per month.

Statistical analysis

We described the prevalence of severe hypertension among the overall study population and among participants with hypertension. We calculated the age–sex-standardized prevalence of severe hypertension by adjusting observation weights to match the age–sex distributions in the 2010 Chinese Census [14]. We then described the characteristics of participants with severe hypertension and compared these with normotensive and less severe hypertensive participants separately.

We assessed the awareness rate among individuals with untreated severe hypertension. We did not assess the awareness rate among treated participants as some treated participants with severe hypertension may have adequately lowered their blood pressure and moved to the controlled hypertensive group, resulting in underestimating awareness rate among those having severe hypertension despite treatment.

Among participants who had severe hypertension despite treatment, we assessed the number and class of medication they reported using. Medication usage was divided into six medication classes defined by the 2010 Chinese guidelines for the management of hypertension [12], including angiotensin-converting enzyme inhibitor (ACEI) or angiotensin receptor blocker (ARB), beta-blockers, calcium channel blockers (CCB), diuretics, and fixed-dose combination drugs. Information on the traditional Chinese medications (TCMs) used for hypertension was also collected, and we listed the top 10 TCMs used by these participants.

Lastly, we developed two multivariable mixed models with a logit link function and township-specific random intercepts (to account for geographic autocorrelation) to identify individual characteristics associated with the prevalence of severe hypertension among all study participants, and the awareness of hypertension among participants with untreated severe hypertension. Explanatory variables included participants' age, sex, marital status, annual

household income, education level, occupation, geographical region, health insurance status, current smoking, current drinking, obesity, physician-diagnosed diabetes, and prior cardiovascular events (myocardial infarction or stroke).

We excluded participants with missing values for age, sex, household income, education, or BMI. P less than 0.05 was considered statistically significant. All analyses were conducted with SAS 9.4 (SAS Institute Inc., Cary, North Carolina, USA) in 2019.

RESULTS

Our sample included 2 618 757 people with an average age of 55.6 years [standard deviation (SD), 9.8]; 59.6% were women (Supplemental Table S1, http://links.lww.com/ HJH/B477 and Supplemental Figure S1, http://link-s.lww.com/HJH/B477). The distribution of people by age differed from that in the 2010 Chinese Census. Our sample had more people from the middle-aged groups (e.g. 50–54, 55–59, and 60–64 years) and fewer people from the younger or older age groups (e.g. 35–39, 40–44, 65–69, and 70–75 years).

Prevalence and characteristics of participants with severe hypertension

In the study cohort of 2 618 757 individuals, 14.5% (378 457) had severe hypertension and 31.3% (820 712) had less severe hypertension. Among those with severe hypertension, 61.3% had isolated systolic severe hypertension (SBP ≥160 mmHg but DBP < 100 mmHg), 12.8% had isolated diastolic severe hypertension (DBP ≥ 100 mmHg but SBP < 160 mmHg), and 26% had combined systolic–diastolic severe hypertension (both SBP ≥160 mmHg and DBP ≥100 mmHg; Table 1 and Fig. 1). Of the entire cohort, 2.9% had an SBP at least 180 mmHg. The prevalence of severe hypertension increased with age in both men and women (Fig. 2). Compared with people who had less severe hypertension, those who had severe hypertension were older, more likely to have lower annual household income, lower educational status, currently smoke, currently drink, have diabetes, obesity, and prior cardiovascular events (Table 1). Characteristics were similar between untreated participants with severe hypertension and participants with severe hypertension despite treatment (Supplemental Table S1, http://links.lww.com/HJH/B477). Using the 2010 Chinese Census data, we reported age–sex-standardized rate of severe hypertension to be 11.6%.

In multivariable logistic regression analysis, we identified several individual characteristics independently associated with the prevalence of severe hypertension (Table 2). The odds of having severe hypertension were significantly higher among older adults, women, those who were at least college-educated, currently drinking, and/or who had diabetes, obesity, and prior cardiovascular events (all P < 0.01). Participants who were married, farmers, and current smokers had significantly lower odds of having severe hypertension (all P < 0.01). Health insurance did not have a significant association with severe hypertension.

Awareness of having hypertension among untreated participants with severe hypertension

Among untreated participants with severe hypertension (n = 222 589 or 58.8% of the overall severe hypertension group), only 60 540 (27.1%) were aware of their conditions. The awareness rate increased with age and was higher among those from the rural areas (Fig. 3). Awareness was significantly higher among severe hypertensive participants who were older, women, farmers, current smokers, current drinkers, resided in the Eastern region, and those who had diabetes, obesity, and prior cardiovascular events (all P < 0.01, Table 2). Participants' education and income were not independently associated with their awareness of having severe hypertension.

Reported use of antihypertensive medication among participants with severe hypertension despite treatment

Among participants who had severe hypertension despite treatment, 84.7% reported using one medication, 14% two, and 1.3% three or more (Fig. 4). The reported use of combination therapy increased slightly with age; however, only 15% of the participants reported use of combination therapy. This percentage was consistent across all age groups. The reported use of combination therapy among participants with severe hypertension was similar to that among those with less severe hypertension (14.1% using two medications, and 1.3% using three or more, P = 0.32).

Among participants who reported the names of their medications, CCBs were the most commonly used class (66.4%), followed by ACEIs or ARBs (43.7%) and diuretics (15.1%; Supplemental Figure S2, http://links.lww.com/ HJH/B477); 3.3% used TCMs. Among participants using only one medication, nifedipine was the most common agent (28.9%), followed by amlodipine (5.9%) and nitrendipine (5.4%; Table S2, http://links.lww.com/HJH/B477). Among participants using two medications, nifedipine with captopril was the most frequent combination (6.1%), followed by nifedipine with metoprolol (5.7%) and nifedipine with irbesartan (3.2%). Among participants who reported using TCMs, 'Zhenju Jiangya Pian', a compound of TCM, hydrochlorothiazide, and clonidine hydrochloride shown to exert its antihypertensive effect by increasing the level of nitric oxide and preventing endothelial injury [15], was the most frequently used TCM (78.1%, Supplemental Table S3, http://links.lww.com/HJH/B477). About a third (35.1%) of treated patients did not report the names of their medications.

DISCUSSION

In this national study, one in eight adults aged 35–75 years had severe hypertension, affecting approximately 70 million of the total population in China. We found that about 60% of those with severe hypertension were not treated with any medications. Of untreated severe hypertensive participants, fewer than one-third were aware of their condition. Of severe hypertensive participants despite treatment, combination therapies, the first-line treatments

TABLE 1. Baseline characteristics of patients with severe hypertension compared with less severe hypertension and normotensive

| Characteristics, n (%) n (%)	All participant 2 618 757	Normotensive (SBP <140 mmHg and DBP <90 mmHg) 1 577 528	Less severe hypertension (SBP between 140 and 159 mmHg or DBP between 90 and 99 mmHg) 820 712	Severe hypertension (SBP ≥160 mmHg or DBP ≥100 mmHg) 378 457
Age (years)				
35–39	132 957 (5.1%)	112 355 (7.1%)	17 153 (2.1%)	6969 (1.8%)
40–44	267 327 (10.2%)	209 188 (13.3%)	48 603 (5.9%)	19 022 (5%)
45–49	379 375 (14.5%)	268 745 (17%)	91 227 (11.1%)	37 598 (9.9%)
50–54	449 286 (17.2%)	281 603 (17.9%)	136 901 (16.7%)	58 039 (15.3%)
55–59	369 390 (14.1%)	211 086 (13.4%)	127 420 (15.5%)	55 792 (14.7%)
60–64	449 190 (17.2%)	233 435 (14.8%)	168 889 (20.6%)	79 159 (20.9%)
65–69	350 172 (13.4%)	165 202 (10.5%)	140 052 (17.1%)	70 937 (18.7%)
70–75	221 060 (8.4%)	95 914 (6.1%)	90 467 (11%)	50 941 (13.5%)
Sex				
Men	1 059 269 (40.4%)	617 304 (39.1%)	354 802 (43.2%)	158 595 (41.9%)
Women	1 559 488 (59.6%)	960 224 (60.9%)	465 910 (56.8%)	219 862 (58.1%)
Urbanity				
Urban	1 050 854 (40.1%)	668 839 (42.4%)	303 811 (37%)	135 046 (35.7%)
Rural	1 567 903 (59.9%)	908 689 (57.6%)	516 901 (63%)	243 411 (64.3%)
Region				
Eastern	960 316 (36.7%)	565 864 (35.9%)	313 833 (38.2%)	138 067 (36.5%)
Western	922 257 (35.2%)	579 647 (36.7%)	266 007 (32.4%)	132 610 (35%)
Central	736 184 (28.1%)	432 017 (27.4%)	240 872 (29.3%)	107 780 (28.5%)
Education				
Primary school or lower	1 132 532 (43.2%)	619 616 (39.3%)	395 593 (48.2%)	192 441 (50.8%)
Middle school	840 815 (32.1%)	523 651 (33.2%)	254 952 (31.1%)	110 583 (29.2%)
High school	408 055 (15.6%)	267 898 (17%)	113 055 (13.8%)	49 218 (13%)
College or above	202 170 (7.7%)	144 668 (9.2%)	46 544 (5.7%)	21 066 (5.6%)
Unknown[a]	35 185 (1.3%)	21 695 (1.4%)	10 568 (1.3%)	5149 (1.4%)
Household income (Yuan/year)				
<10 000	526 106 (20.1%)	293 705 (18.6%)	178 275 (21.7%)	89 611 (23.7%)
10 000–50 000	1 425 953 (54.5%)	859 549 (54.5%)	448 701 (54.7%)	203 382 (53.7%)
> 50 000	428 493 (16.4%)	279 571 (17.7%)	120 488 (14.7%)	50 638 (13.4%)
Unknown[a]	238 205 (9.1%)	144 703 (9.2%)	73 248 (8.9%)	34 826 (9.2%)
Marital status				
Married	2 433 980 (92.9%)	1 479 635 (93.8%)	754 779 (92%)	345 105 (91.2%)
Widowed, separated, divorced, single	153 345 (5.9%)	78 449 (5%)	56 600 (6.9%)	28 503 (7.5%)
Unknown[a]	31 432 (1.2%)	19 444 (1.2%)	9333 (1.1%)	4849 (1.3%)
Health insurance status				
Insured	2 561 979 (97.8%)	1 541 509 (97.7%)	804 477 (98%)	370 639 (97.9%)
Uninsured	16 613 (0.6%)	10 758 (0.7%)	4725 (0.6%)	1978 (0.5%)
Unknown[a]	40 165 (1.5%)	25 261 (1.6%)	11 510 (1.4%)	5840 (1.5%)
Medical history				
Myocardial infarction	19 538 (0.7%)	9487 (0.6%)	7772 (0.9%)	3780 (1%)
Stroke	62 786 (2.4%)	24 489 (1.6%)	28 372 (3.5%)	16 314 (4.3%)
Diabetes Mellitus	170 414 (6.5%)	75 451 (4.8%)	71 583 (8.7%)	37 215 (9.8%)
Cardiovascular disease risk factor				
Current smoker	510 079 (19.5%)	300 782 (19.1%)	167 893 (20.5%)	75 468 (19.9%)
Current drinker	627 376 (24%)	355 793 (22.6%)	217 528 (26.5%)	98 684 (26.1%)
Obesity	406 131 (15.5%)	174 396 (11.1%)	178 187 (21.7%)	93 940 (24.8%)

CVD, cardiovascular disease.

[a]Participants with missing data on covariates were analyzed as a separate subgroup of 'unknown'.

recommendation for severe hypertension, were used in only 15% of the participants. Given that most of the patients were untreated or undertreated, these findings highlight immense opportunities to improve the diagnosis and treatment of this extremely high-risk group in China.

This study extends the scientific literature in two important ways. First, we used detailed information on community residents from a large population-based study to better characterize the population with severe hypertension in China. Previous studies have shown that severe hypertension was prevalent [6]. We have now provided a more granular view of the population pattern and patient treatment – in addition to the awareness of the condition – in the overall study population, as well as across a wide variety of subgroups. Our results reveal that severe hypertension affects a substantial proportion of people consistently across diverse population subgroups, suggesting that a national approach is warranted to mitigate severe hypertension and its harmful effects. Compared with findings from Western countries, such as the United States and United Kingdom, the prevalence of severe hypertension in China is nearly five-fold higher [16,17]. We further showed that older adults, women, those who were at least college-educated, currently drinking, and/or had diabetes, obesity, and prior cardiovascular events are more likely to have severe hypertension, which indicates that screening
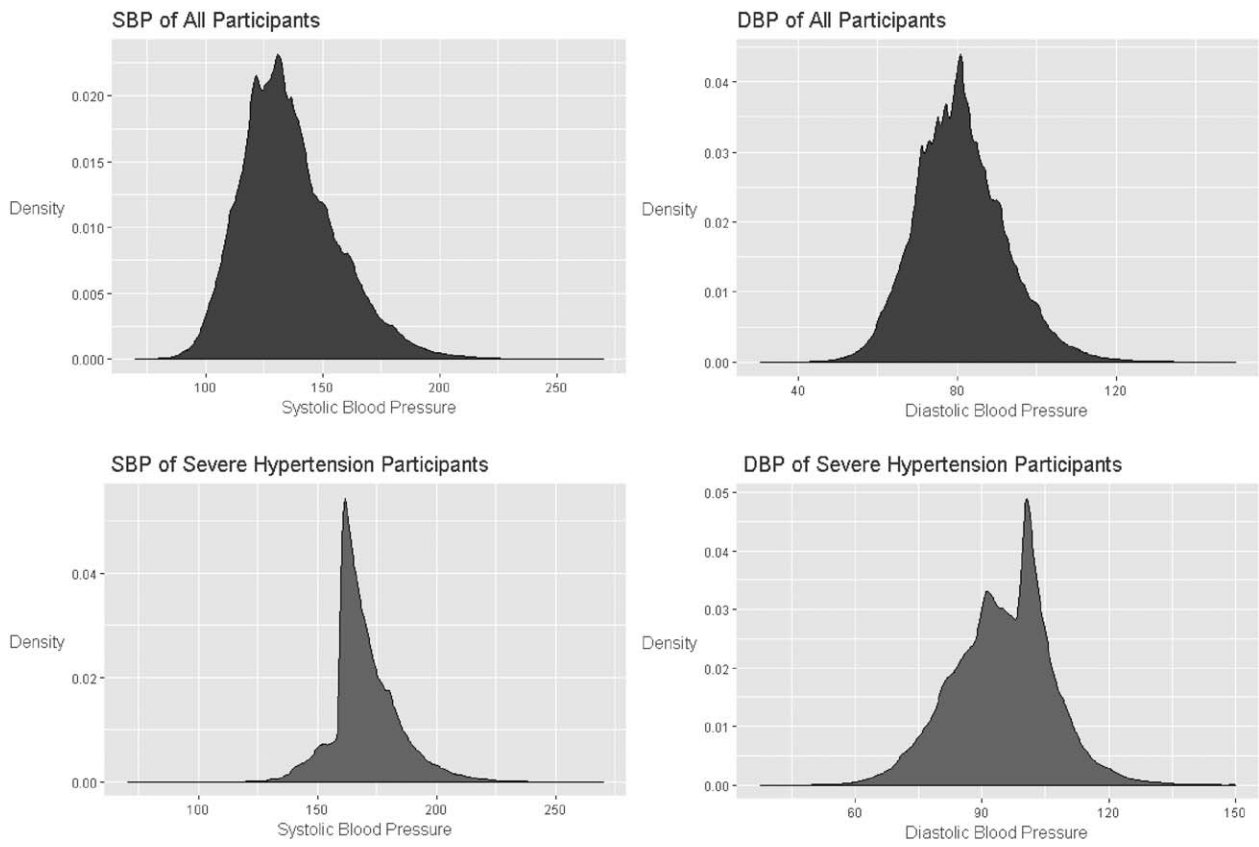
FIGURE 1 Distributions of SBP and DBP among all participants and among severe hypertensive participants.
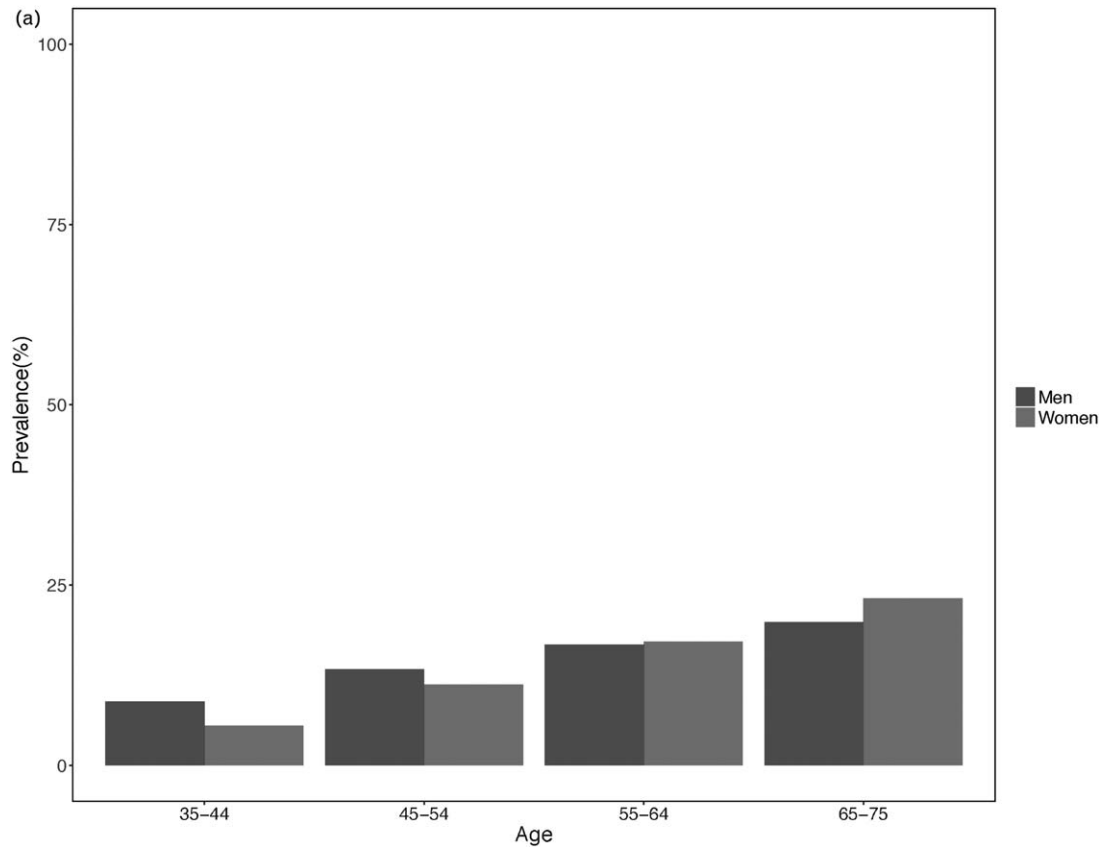
FIGURE 2 Prevalence of (a) severe hypertension and (b) SBP at least 180 mmHg among all study participants.
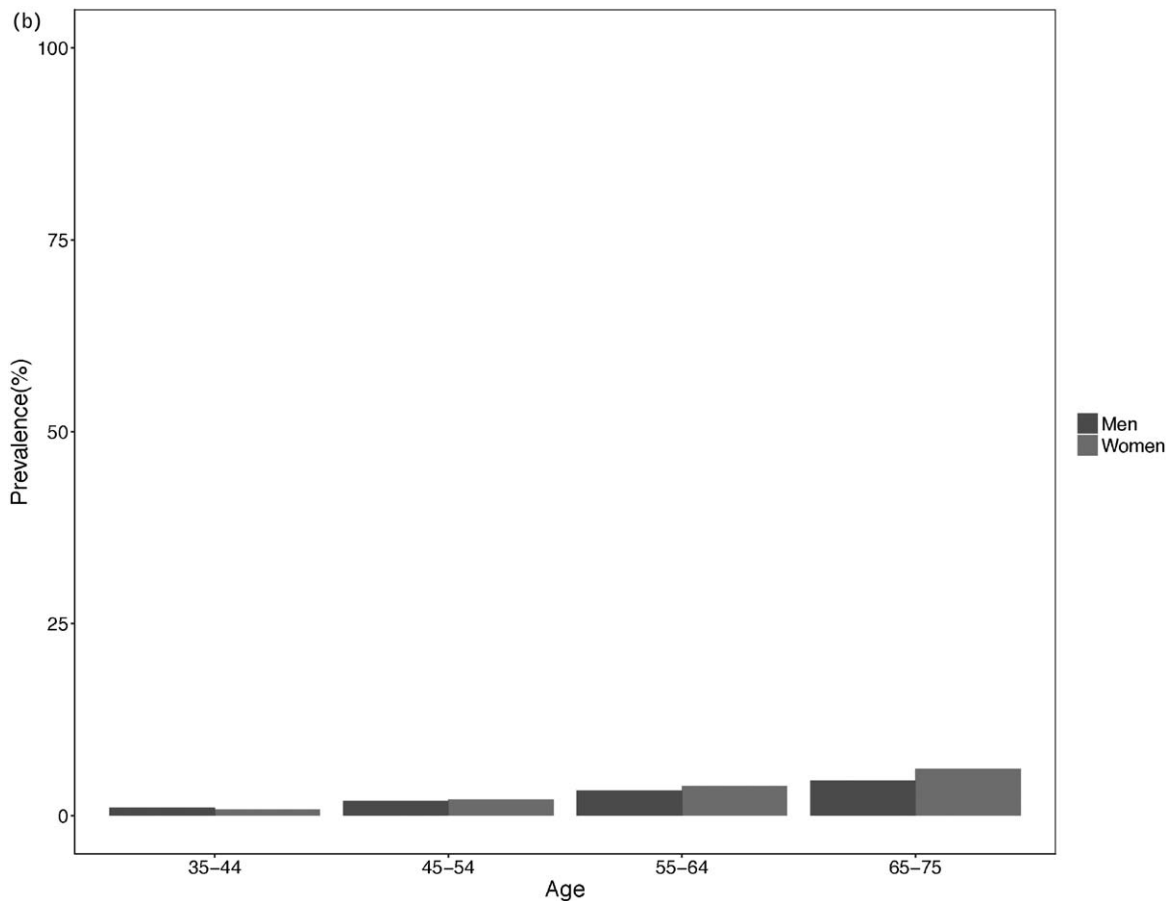
FIGURE 2 (Continued).

should be targeted at these high-risk population subgroups for cardiovascular primary prevention.

Second, we analyzed the use of antihypertensive medications among treated participants with severe hypertension to better identify potential targets for intervention. People who continue to have severe elevation of blood pressure despite treatment are either inadequately treated or whether they have resistant hypertension (defined as blood pressure that remains above the target level despite concurrent use of three antihypertensive agents of different classes) [1,7,8]. Although clinical guidelines recommend at least two antihypertensive agents for people with severe hypertension [1,8,12], the vast majority of patients in our study were treated with only one class of antihypertensive medication, and thus continued to have severe hypertension despite treatment. The usage rates of combination therapies are much lower than those in other countries [16,18] for a few potential reasons. At the patient level, low health literacy and self-management capability may contribute to poor adherence to medications, lifestyle, and follow-up care with their physicians [19]. At the provider level, primary care physicians in China commonly have low levels of training and experience high rates of burnout [20,21]. As hypertension management requires regular monitoring and follow-up, the limited capability of primary care providers may impede appropriate treatment initiation and intensification. At the population level, lack of access to
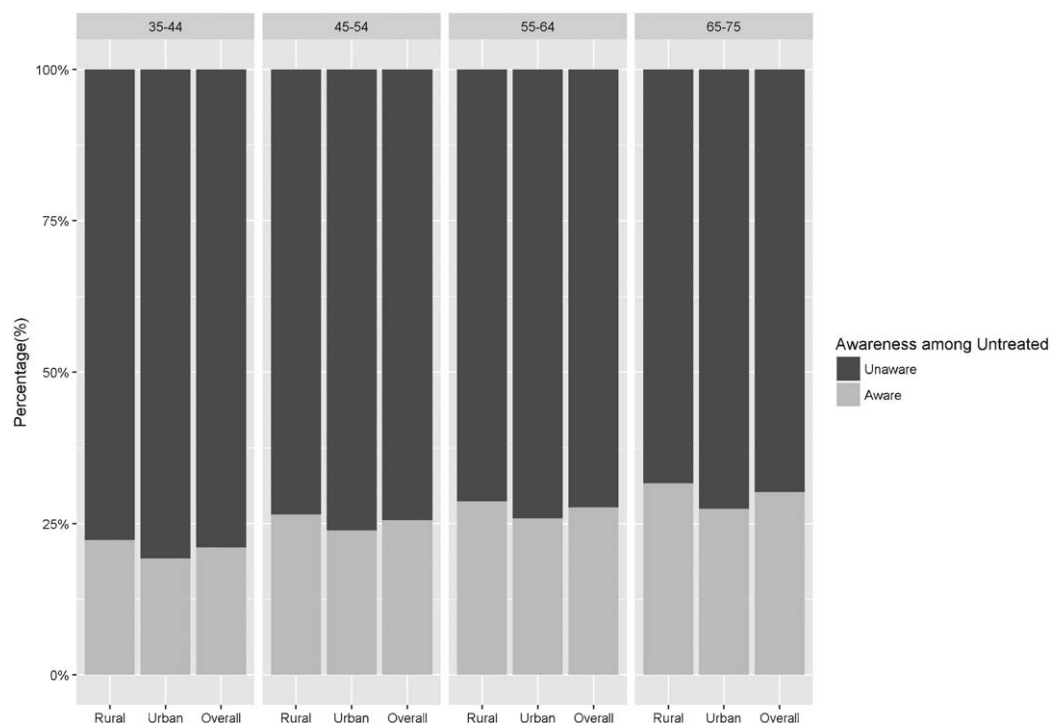
affordable antihypertensive medications also contributes to inadequate treatment and subsequent poor control of blood pressure [22,23]. Collectively, these findings highlight the need for a multilevel intervention that addresses the patient, provider, and health system factors to improve the treatment and control of blood pressure.

Our findings have important clinical and policy implications. Stroke is the leading cause of death in China, causing 20% of total deaths annually [24]. As high blood pressure is a major attributable risk factor for stroke [25], the high prevalence of severe hypertension as shown in our study contributes to the large disease burden in the country. In order to reduce the incidence of stroke, efforts to control population blood pressure should be expanded, with specific attention paid to addressing the needs of the subpopulation with severe hypertension. Our findings of the low awareness and treatment rates among patients with severe hypertension indicate that strengthening the primary care system to provide high-quality public health service is critical to improving awareness, treatment, and control of hypertension among community residences. The recent publication of the first national primary care hypertension prevention and management guidelines in 2017 could facilitate the improvement of capability and quality of care of primary healthcare institutions [26]. Additionally, to ensure access to affordable medications, the government has recently committed to provide more generous

TABLE 2. Individual characteristics associated with the prevalence of severe hypertension in all participants and the awareness among untreated severe hypertensive participants

	Prevalence of severe hypertension among all participants		Awareness among untreated severe hypertensive participants	
	Odds ratio (95% CI)	P value	Odds ratio (95% CI)	P value
Age				
35–44	1		1	
45–54	1.81 (1.78–1.84)	<0.001	1.23 (1.18–1.28)	<0.001
55–64	2.76 (2.72–2.81)	<0.001	1.33 (1.27–1.38)	<0.001
65–75	4.33 (4.26–4.41)	<0.001	1.47 (1.39–1.54)	<0.001
Sex				
Men	1		1	
Women	1.02 (1.01–1.03)	0.001	1.05 (1.02–1.08)	0.001
Marital status				
Not married	1		1	
Married	0.90 (0.89–0.92)	<0.001	0.95 (0.90–0.99)	0.030
Annual household income (Yuan/year)				
<10 000	1		1	
10 000–50 000	0.94 (0.93–0.95)	<0.001	0.93 (0.90–0.96)	<0.001
>50 000	0.94 (0.92–0.95)	<0.001	0.95 (0.91–1.00)	0.039
Education level				
Lower than college	1		1	
College or above	1.07 (1.05–1.09)	<0.001	1.05 (1.00–1.10)	0.054
Occupation				
Not farmer	1		1	
Farmer	0.97 (0.95–0.98)	<0.001	1.10 (1.06–1.14)	<0.001
Health insurance status				
Insured	1		1	
Uninsured	0.96 (0.91–1.02)	0.224	0.84 (0.71–0.98)	0.029
CVD risk factor				
Current smoker	0.98 (0.97–0.99)	<0.001	1.13 (1.09–1.16)	<0.001
Current drinker	1.57 (1.55–1.59)	<0.001	1.07 (1.03–1.11)	<0.001
Diabetes mellitus	1.47 (1.45–1.49)	<0.001	2.13 (2.04–2.23)	<0.001
Obesity	2.13 (2.11–2.15)	<0.001	1.32 (1.28–1.35)	<0.001
Prior CVD	1.55 (1.52–1.59)	<0.001	2.21 (2.08–2.34)	<0.001
Geographic region				
Western	1		1	
Eastern	0.89 (0.83–0.94)	0.001	0.61 (0.56–0.68)	<0.001
Central	1.31 (1.23–1.39)	<0.001	0.91 (0.82–1.00)	0.134

CI, confidence interval; CVD, cardiovascular disease.

FIGURE 3 Awareness of having hypertension among untreated severe hypertensive participants, by urbanity and age.
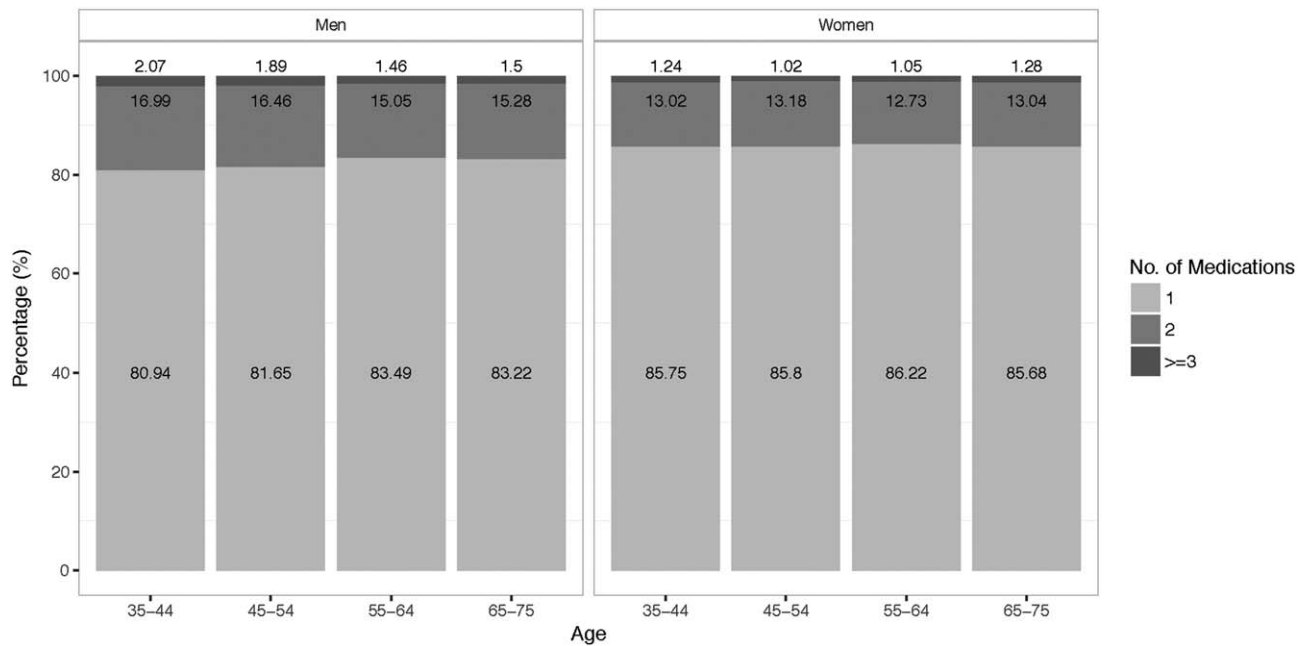
FIGURE 4 Number of antihypertensive medications used among treated severe hypertensive participants, by age and sex.

reimbursement for antihypertensive medications [27]. These efforts are still being implemented; however, and will need further evaluation for their effectiveness.

From a patient's perspective, severe hypertension represents an extreme phenotype that puts the patient at high risk of target organ damage and cardiovascular mortality. Current guidelines recommend a more extensive treatment and follow-up regime for patients with severe hypertension to reduce blood pressure and cardiovascular risk than for those patients with less severe hypertension [1,8,12]. As clinicians and public health professionals develop and implement strategies to improve individual clinical care and to control blood pressure, our findings of the suboptimal use of combination therapies suggest that improvements in physician training and patient education are likely to enhance guideline adherence for hypertension management.

Our study has several potential limitations. First, for estimation of characteristics and prevalence of participants with severe hypertension, we classified patients based on the blood pressure value at enrollment, irrespective of their medication use. As such, some treated severe hypertensive participants may have had their blood pressure reduced with medication and may have been included in the less severe hypertension or normotensive group. Second, our study used a purposive sampling method for rapid, large-scale recruitment. This could have resulted in an overestimation of the awareness and treatment rates as study participants, by virtue of responding to this screening project, would be more likely to be connected with the health system. Nevertheless, there are reasons to believe that our sample provides a reasonable estimation of the Chinese population. The age–sex-standardized estimates for prevalence of severe hypertension based on the 2010 Chinese Census data are consistent with our main results. Compared with findings from the most recent, nationally

representative China Hypertension Survey in 2012–2015, the prevalence of severe hypertension in our study is consistent for the corresponding age groups [2]. Third, the use of antihypertensive drugs was self-reported, which could be subject to recall bias and lead to an underestimation of the medication use. However, it is uncommon for an individual to forget a medication, which has been taken for a long time. Fourth, given the consideration of operational feasibility, we measured blood pressure twice on the participant's right arm as opposed to doing three measurements on both arms, as recommended by the clinical guidelines [8]. Finally, we did not use ambulatory blood pressure measurements in this study, and therefore, we were unable to identify white-coat hypertension.

In conclusion, severe hypertension affects a large number of adults in China, and these patients have an exceptionally high risk of complications and adverse cardiovascular outcomes. However, many patients with severe hypertension have low awareness of having hypertension, and most treatment of participants with severe hypertension is inadequate. Our findings suggest that efforts to optimize blood pressure in the Chinese population should be expanded, with special attention paid to treating the subpopulation with severe hypertension.

ACKNOWLEDGEMENTS

Xinyue Li, PhD; Xiaochen Wang, PhD; Daqi Sun, MS; Siyun He, MS; Zihan Jiang, MD; Jiamin Liu, MD; Na Tian, BS; Xiaofang Yan, MS; Hao Yang, BS; Hongyu Zhao, PhD; Wade L. Schulz, MD, PhD, Khurram Nasir, MD; Frederick A. Masoudi, MD, MSPH; Harlan M. Krumholz, MD**; Jing Li, MD PhD** (*Joint first authors; **Joint senior authors; F.F.J.Lu, J.Liu, N.T, X.Y, H.Y, J.Li from National Clinical Research Center for Cardiovascular Diseases, NHC Key Laboratory of Clinical Research for Cardiovascular Medications, State Key Laboratory of Cardiovascular Disease, Fuwai Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, National Center for Cardiovascular Diseases, Beijing, China; Y.L. W.L.S., H.M.K from Center for Outcomes Research and Evaluation, Yale-New Haven Hospital, and Section of Cardiovascular Medicine, Department of Internal Medicine, Yale School of Medicine, New Haven, Connecticut, USA; X.L., X.W., D.S., S.H., H.Z from Department of Biostatistics, Yale University, New Haven, Connecticut, USA; Z.J. from Healthcare and International Medical Services, Peking Union Medical College Hospital, Beijing, People's Republic, of China; K.N. from Division of Cardiovascular Prevention and Wellness, Houston Methodist DeBakey Heart and Vascular Center, and Center for Outcomes Research, Houston Methodist Research Institute, Houston, Texas, USA; F.A.M from Division of Cardiology, University of Colorado Anschutz Medical Campus, Aurora, Colorado, USA).

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Conflicts of interest

J.L. is a recipient of research grants from the government of China, through Fuwai Hospital, for research to improve the management of hypertension and lipids, and to improve care quality and patient outcomes of cardiovascular disease; is a recipient of research agreements with Amgen, through National Center for Cardiovascular Diseases (NCCD) and Fuwai Hospital, for a multicenter trial to assess the efficacy and safety of Omecamtiv Mecarbil, and for dyslipidemic patient registration; is a recipient of a research agreement with Sanofi, through Fuwai Hospital, for a multicenter trial on the effects of sotagliflozin; is a recipient of a research agreement with University of Oxford, through Fuwai Hospital, for a multicenter trial of empagliflozin; and was a recipient of a research agreement, through NCCD, from AstraZeneca for clinical research methods training. H.M.K. discloses that he is a recipient of a research grant, through Yale, from Medtronic and the U.S. Food and Drug Administration to develop methods for postmarket surveillance of medical devices; is a recipient of research agreements with Medtronic and Johnson & Johnson (Janssen), through Yale, to develop methods of clinical trial data sharing; works under contract with the Centers for Medicare & Medicaid Services, through Yale, to develop and maintain performance measures that are publicly reported; was a recipient of a research agreement, through Yale, from the Shenzhen Center for Health

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