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ORIGINAL RESEARCH

Trends in Antihypertensive Drug Use and Irrational Prescriptions Among Elderly Patients in China (2016–2023): A Nationwide Multi-Center Cross-Sectional Survey Study

Dongsheng Hong[1,2], Weihao Chen[1,3], Shuangshuang Du[1,4], Jinshuai Ren[1], Duo Lv[1], Wenya Shan[1], Xiaoyang Lu[1,2], Qingwei Zhao[1,2]

[1]Department of Clinical Pharmacy, Zhejiang Provincial Engineering Center for Innovative Drug Clinical Research and Application, Zhejiang Provincial Key Laboratory of Traditional Chinese Medicine for Clinical Evaluation and Translational Research, The First Affiliated Hospital, Zhejiang University School of Medicine, Hangzhou, People's Republic of China; [2]Zhejiang Provincial Hospital Pharmacy Management Quality Control Center, Hangzhou, People's Republic of China; [3]College of Pharmaceutical Sciences, Zhejiang University, Hangzhou, People's Republic of China; [4]College of Pharmacy, Wenzhou Medical University, Wenzhou, People's Republic of China

Correspondence: Xiaoyang Lu; Qingwei Zhao, Department of Clinical Pharmacy, Zhejiang Provincial Engineering Center for Innovative Drug Clinical Research and Application, Zhejiang Provincial Key Laboratory of Traditional Chinese Medicine for Clinical Evaluation and Translational Research, The First Affiliated Hospital, Zhejiang University School of Medicine Hangzhou, 79 Qingchun Road, Hangzhou, 310003, People's Republic of China, Email luxiaoyang@zju.edu.cn; qwzhao@zju.edu.cn

Purpose: Hypertension is a common chronic condition among the elderly, and the rational use of antihypertensive medications is critical for blood pressure control. This study aimed to investigate trends in the use and irrational prescription of antihypertensive medications among elderly patients with hypertension in China from 2016 to 2023.

Patients and Methods: A retrospective cross-sectional design was applied to analyze the prescription of antihypertensive drugs in hypertensive patients aged 65 years and above, utilizing outpatient electronic medical record data from 78 hospitals in nine cities in China from 2016 to 2023. Antihypertensive medications were categorized into nine classes based on hypertension treatment guidelines. Annual trends in the use of these medications were analyzed using Annual Percentage Change (APC). Irrational prescriptions were defined as contraindicated medication prescriptions and inappropriate combination medication. Poisson regression models were employed to analyze trends and influencing factors for irrational prescriptions.

Results: The number of patients increased from 396,408 to 542,215 during the study period. Calcium Channel Blockers had the highest usage but showed a slight decrease (APC=−3.46%, P=0.011), while β-blockers showed a slight increase (APC=1.48%, P=0.028). The overall proportion of first-line antihypertensive prescriptions was 97.47% but showed a slight declining trend (APC=−0.66%, P=0.004). The rates of inappropriate combination medication and overall irrational prescriptions decreased, while the rate of contraindicated medication prescriptions increased (P<0.001). Factors including male gender, advanced age (≥85 years), northern regions, primary healthcare settings, and geriatrics departments were associated with higher risks of contraindicated medications.

Conclusion: This study reveals the trends and patterns in antihypertensive medication use among elderly hypertensive patients in China from 2016 to 2023. While the overall use of first-line antihypertensive drugs remained high, there were differences across subgroups. The increasing rate of contraindicated medications and the identification of high-risk groups and clinical settings provide important insights for optimizing antihypertensive treatment in elderly populations.

Keywords: elderly hypertension, antihypertensive medication, irrational prescription, trend analysis, contraindicated medication

Introduction

Hypertension is a major risk factor for cardiovascular and cerebrovascular diseases, with its prevalence increasing with age.[1,2] In China, the prevalence of hypertension among individuals aged 60 years and older is as high as 53.24%.[3] Antihypertensive medication is the cornerstone of hypertension management, and its appropriate use can

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effectively control blood pressure and reduce the risk of cardiovascular events.[4,5] However, irrational use of antihypertensive drugs is not uncommon in clinical practice, particularly among the elderly, such as medication prescribed beyond contraindications and inappropriate combination medication.[6] Irrational prescriptions of antihypertensive drugs can lead to adverse drug reactions, treatment failure, and increased healthcare costs.

Although several previous studies have systematically investigated the treatment and control of hypertension in China, with a reported prevalence of 24.7% nationwide, surging to 44.7% in specific samples, control was found to be inadequate in an estimated 240 million out of approximately 274 million adults with hypertension, further emphasizing that research on the rational use of antihypertensive drugs remains insufficient.[7–9] Most studies focused on the general population, with shorter research periods or limited assessment of prescription appropriateness.[10,11] Currently, the trends and influencing factors of irrational antihypertensive drug prescriptions among elderly hypertensive patients in China remain unclear. Given the high prevalence of hypertension in this population and their susceptibility to drug-related problems, evaluating the current status and trends of antihypertensive drug prescriptions and identifying factors associated with irrational prescribing is crucial for optimizing medication use and guiding clinical practice. This study utilizes data from a large national multi-center hospital prescription analysis collaboration project to investigate trends in the use of antihypertensive drugs and irrational prescribing among elderly hypertensive patients in China from 2016 to 2023. Additionally, it explores patient-, regional-, and healthcare institution-related factors which influence prescription patterns, aiming to identify potential issues in antihypertensive drug use and provide references for clinical practice and policy development.

Patients and Methods

Study Design and Participants

This study employed a retrospective cross-sectional design, focusing on hypertensive outpatients aged 65 years and older. Prescription data from January 2016 to December 2023 were collected through the China Hospital Prescription Analysis Collaboration Project (CHPA).[12] CHPA is a nationwide survey of clinical medication practices, including prescription data from public hospitals in nine Chinese cities (Beijing, Tianjin, Shenyang, Harbin, Zhengzhou, Shanghai, Hangzhou, Chengdu, and Guangzhou). Each year, data from 40 randomly selected working days per hospital are analyzed, making it a widely used resource in pharmacoepidemiology research in China.[13,14] Patient confidentiality was maintained throughout the study, adhering to the requirements of the *Declaration of Helsinki*. This study followed the reporting guidelines for observational studies (Table S1). [15]

Inclusion and Exclusion Criteria

Our study comprised all data from the CHPA that met inclusion and exclusion criteria, including patient demographics, clinical diagnoses, prescribed medication names, hospital geographic regions, hospital levels, and department names. Inclusion criteria: (1) Diagnosed with hypertension, with or without comorbidities. (2) Aged ≥65 years, regardless of gender. (3) Data from hospitals continuously participating in the project from 2016 to 2023. Exclusion criteria: (1) Secondary hypertension. (2) Incomplete data.

Drug Classification

Drug names were standardized based on their generic names for chemical drugs. Following hypertension treatment guidelines, antihypertensive drugs were categorized into nine classes: Angiotensin II receptor blockers (ARBs), Angiotensin-converting enzyme inhibitors (ACEIs), Calcium channel blockers (CCBs), β-blockers, Diuretics, $\alpha\beta$-blockers, α-blockers, Centrally acting antihypertensive drugs and single-pill combinations (SPCs). SPCs considered in this study were primarily combinations of ARBs, ACEIs, CCBs, β-blockers, and diuretics. Following the guidelines, ARBs, ACEIs, CCBs, β-blockers, diuretics, and SPCs were defined as first-line medications.[4]

Definition of Irrational Drug Use

Based on the *Guidelines for Rational Use of Antihypertensive Drugs (2nd Edition)*, irrational drug use was classified into two categories: Drug use beyond contraindications, including (1) Use of ARBs or ACEIs in patients with hyperkalemia.

(2) Use of β-blockers in patients with bronchial asthma or atrioventricular conduction block. (3) Use of thiazide diuretics in patients with gout. (4) Use of aldosterone receptor antagonists in patients with renal failure, which was defined based on the diagnosis in the patients' prescriptions. Inappropriate combination medication, including: (1) Concurrent use of ARBs and ACEIs. (2) Combining multiple drugs within the same class of antihypertensives.[16]

Statistical Analysis

Statistical analyses were performed using R language (version 4.2.1). Categorical data were expressed as counts and percentages. Trends in annual drug utilization rates were analyzed using the annual percentage change (APC), calculated from the logarithmic linear regression model: $\ln(r)=\alpha+\beta x+u$, where r represents drug utilization rates, x is the year, α is the constant term, β is the regression coefficient, and u is the random error term.[17,18] APC was derived as follows: $APC=100\times(e\beta-1)$. If the APC is negative (-), it signifies a decreasing trend, while a positive (+) APC indicates an increasing trend. A Poisson regression model was used to analyze trends and factors influencing irrational drug use.[19] Independent variables included patient gender, age group (60–74 years, 75–84 years, ≥85 years), prescription year, region, hospital level, and department type. P <0.05 was considered statistically significant. Data management was conducted using MySQL 8.0.33.

Results

Characteristics of Included Prescriptions and Overall Trends

A total of 3,640,453 antihypertensive prescriptions for patients aged ≥65 years were included, spanning 78 hospitals across 9 cities in china, after excluding patients with secondary hypertension and those with incomplete data. The geographical distribution of these hospitals is detailed in Table S2. The number of patients was 396,408 in 2016, and 542,215 in 2023, showing an upward trend. Most prescriptions were from southern regions (64.82%) and tertiary hospitals (90.05%). Slightly more females were included than males (50.09% vs 49.91%), and the majority of patients were aged 65–74 years (52.31%). Patients visiting specialized departments (eg, cardiology) accounted for 37.17%. During the study period, the proportion of patients aged 65–74 years increased from 47.37% to 56.81%. Emergency and general outpatient visits also showed an increasing trend (Table 1).

Table 1 Demographic and Clinical Characteristics of Antihypertensive Drug Prescriptions in Elderly Hypertensive Patients in China (2016–2023)

Character	2016 (n=396408)	2017 (n=415916)	2018 (n=416765)	2019 (n=420278)	2020 (n=308909)	2021 (n=568255)	2022 (n=571707)	2023 (n=542215)	Total (n=3640453)
Sex (%)									
Male	48.81	48.55	48.59	48.57	48.6	51.25	51.5	51.5	49.91
Female	51.19	51.45	51.41	51.43	51.4	48.75	48.5	48.5	50.09
Age (years, %)									
65~74	47.37	48.4	50.03	51.82	53.16	53.52	54.65	56.81	52.31
75~84	39.49	37.44	35.2	33.31	31.65	30.83	30.2	29.92	33.15
≥85	13.14	14.16	14.77	14.86	15.19	15.65	15.14	13.27	14.54
Region (%)									
Northern	38.4	36.89	36.64	38.43	36.04	32.9	31.19	33.97	35.18
Southern	61.6	63.11	63.36	61.57	63.96	67.1	68.81	66.03	64.82
Hospital Grade (%)									
Level 1	2.11	2.65	3.05	3.66	3.83	2.42	2.25	2.36	2.71
Level 2	10.3	10.29	9.66	9.35	9.28	4.38	4.06	4.33	7.24
Level 3	87.59	87.06	87.29	86.99	86.9	93.2	93.69	93.31	90.05
Clinical Department (%)									
GP	4.03	4.54	5.89	6.31	7.16	5.57	6.8	7.24	5.98
CD	35.11	36.02	39.46	39.07	38.01	37.2	36.16	36.91	37.17
GD	8.67	8.26	8.05	7.98	8.23	7.34	6.63	6.48	7.58
OD	52.19	51.19	46.60	46.65	46.60	49.89	50.41	49.37	49.26

(*Continued*)

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Table 1 (Continued).

Character	2016 (n=396408)	2017 (n=415916)	2018 (n=416765)	2019 (n=420278)	2020 (n=308909)	2021 (n=568255)	2022 (n=571707)	2023 (n=542215)	Total (n=3640453)
Drug Category (%)									
ACEI	8.50	8.36	7.75	7.30	6.97	5.14	4.16	3.55	6.19
ARB	32.58	32.33	32.28	31.00	29.21	22.59	21.25	20.30	26.88
CCB	52.85	53.68	55.03	54.39	54.06	46.32	45.80	42.13	49.75
αβ-Blocker	1.86	1.85	1.96	2.17	2.45	2.77	2.88	3.89	2.56
α-Blocker	1.36	1.25	1.27	1.36	1.45	3.70	3.89	4.42	2.56
β-Blocker	30.71	31.07	31.53	31.74	30.75	34.54	34.30	33.02	32.47
CADs	0.37	0.32	0.32	0.28	0.31	0.17	0.16	0.14	0.24
Diuretic	6.16	5.91	5.85	5.86	6.39	11.06	11.15	11.57	8.44
SPC	21.16	21.94	21.90	21.78	22.46	18.29	17.30	16.98	19.84

Notes: Data are expressed as percentage; The region is categorized into Northern and Southern based on geographical divisions in China; Hospital grade is based on the Chinese hospital grading system, where Level 1 indicates primary hospitals, Level 2 indicates secondary hospitals, and Level 3 indicates tertiary hospitals; Clinical departments are categorized into General Practice (GP), Cardiology Department (CD), Geriatrics Department (GD), and Other Departments (OD) based on the specialty of the department where the antihypertensive drug prescription was issued.

Abbreviations: CCB, Calcium Channel Blocker; *β*-blocker, Beta-adrenergic blocking agent; ARB, Angiotensin Receptor Blocker; ACEI, Angiotensin Converting Enzyme Inhibitor; SPC, Single-Pill combination; *αβ*-Blocker, Alpha-Beta adrenergic blocking agent; *α*-Blocker, Alpha-adrenergic blocking agent; CADs, Central antihypertensive drugs.

Trends and Usage of Antihypertensive Drugs

The study analyzed the use of various antihypertensive drugs between 2016 and 2023. CCB, *β*-blockers, ARBs, SPCs, and diuretics were the most used drugs, followed by ACEIs, *α*-blockers, *αβ*-blockers and CHA (Figure 1A). CCB consistently had the highest usage, though their rate decreased slightly during the study period. *β*-blockers showed a relatively stable usage trend with a slight increase, while other drugs exhibited varying trends in prescription rates (Figure 2B).

Table 2 summarizes the annual trends for each drug class. Among first-line drugs, CCBs had the highest prescription rate at 49.75%, but their APC was −3.46% (95% CI: −5.79% to −1.13%, *P*=0.011), showing a downward trend. *β*-blockers showed a modest increase in prescription rate (32.47%) with an APC of 1.48% (95% CI: 0.23% to 2.74%, *P*=0.028). ARBs (26.88%) showed a declining trend with an APC of −7.79% (95% CI: −10.88% to −4.69%, *P*=0.001). Diuretics (8.44%) demonstrated a significant increase (APC=11.41%, 95% CI: 4.67% to 18.15%, *P*=0.006). ACEIs (6.19%) and SPCs (19.84%) showed decreasing trends with APCs of −12.95% (95% CI: −17.30% to −8.60%, *P*<0.001) and −3.86% (95% CI: −6.69% to −1.02%, *P*=0.016), respectively. Among non-first-line drugs, both *αβ*-blockers and *α*-blockers had prescription rates of only 2.56%, but showed significant annual increases, with APCs of 10.16% (95% CI: 7.18% to 13.15%, *P*<0.001) and 20.47% (95% CI: 9.39% to 31.56%, *P*=0.004), respectively. CADs had the lowest prescription rate (0.24%), with a significant declining trend (APC=−14.36%, 95% CI: −20.28% to −8.44%, *P*=0.001).

The prescription rates and trends of antihypertensive medications among elderly hypertensive patients across primary, secondary, and tertiary hospitals in China were characterized in Table S3. In tertiary hospitals, CCBs had the highest prescription rate at 49.57%, but exhibited a decreasing APC, at −3.74%. Conversely, diuretics and *αβ*-blockers showed increasing trends in tertiary hospitals, with APCs of 10.66% and 10.79% respectively. In secondary hospitals, CCBs also had the highest prescription rate at 47.57%, but with a slight decrease in APC, at −0.92%. However, Diuretic and *α*-blockers demonstrated significantly increasing trends in secondary hospitals, with APCs of 20.11% and 29.27% respectively. In primary hospitals, CCBs commanded the highest prescription rate at 61.40%, with a decreasing trend in APC, at −2.15%. Similarly, Diuretic and *α*-blockers also showed increasing trends in primary hospitals, with APCs of 12.09% and 19.26% respectively.

Trend and Subgroup Analysis of the First-Line Antihypertensive Drugs Use

The overall proportion of first-line antihypertensive prescriptions was 97.47% but showed a slight declining trend (APC=−0.66%, *P*=0.004). Subgroup analysis revealed gender differences, with lower usage among males compared to females (96.26% vs 98.68%) and a steeper decline (APC=−1.06% vs −0.25%). The proportion was similar in different age groups (97.32%–97.64%), and the 65–74 age group showed the fastest decline (APC=−0.71%, *P*=0.003). Southern regions had lower usage rates than northern regions (96.99% vs 98.34%) and a faster decline (APC=−0.88% vs −0.23%). Higher-level hospitals had lower first-line drug usage and faster declines, with tertiary hospitals showing an APC of −0.69%

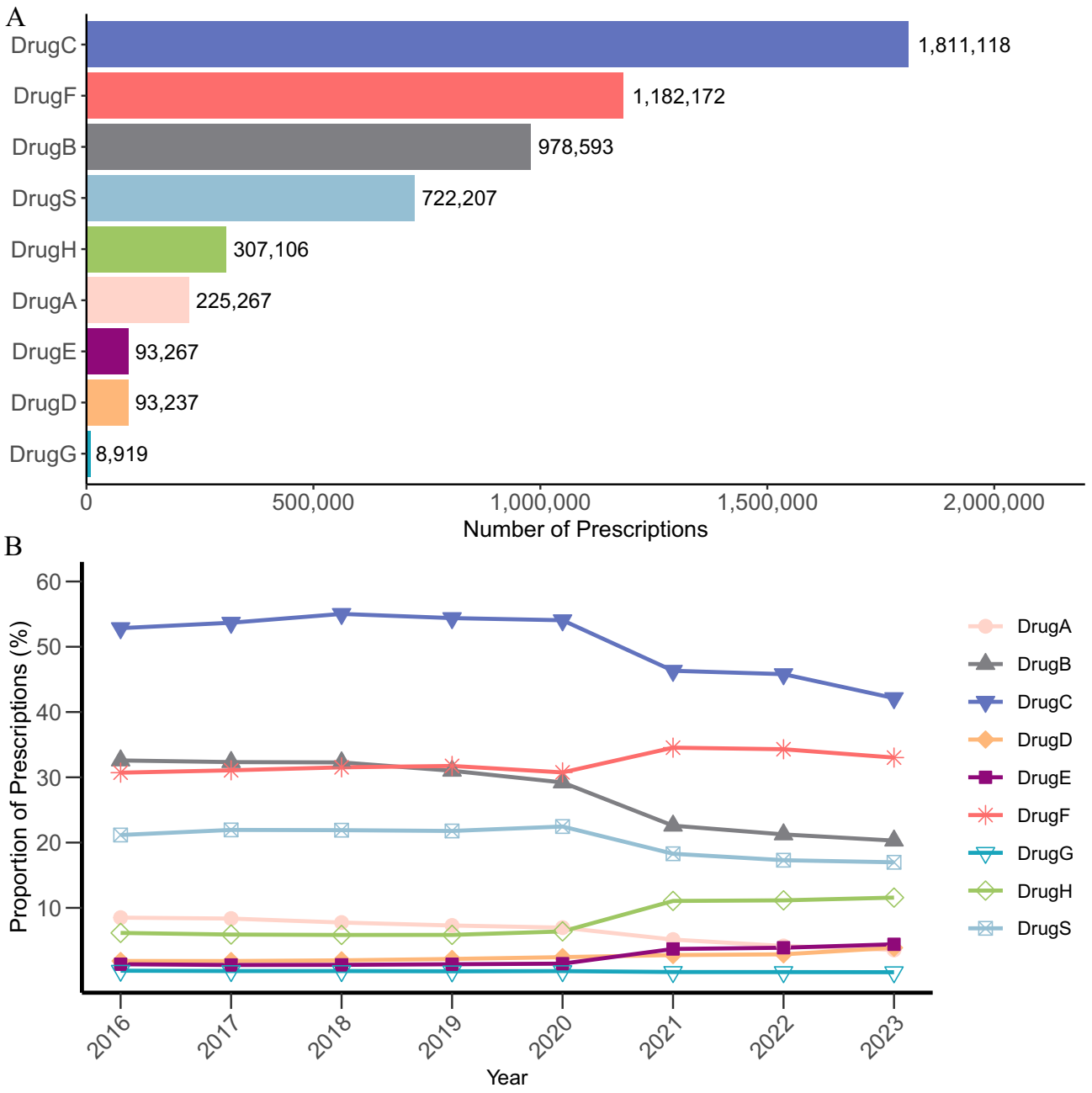

Figure 1 Rankings and Annual Trends of Antihypertensive Drug Utilization Quantities and Rates among Elderly Patients with Hypertension in China (2016–2023).
Notes: (**A**) Rankings of Antihypertensive Drug Utilization Quantities; (**B**) Annual Trends of Antihypertensive Drug Utilization Rates.
Abbreviations: DrugA, Angiotensin Converting Enzyme Inhibitor, DrugB, Angiotensin Receptor Blocker, DrugC, Calcium Channel Blocker, DrugD, Alpha-Beta adrenergic blocking agent, DrugE, Alpha-adrenergic blocking agent, DrugF, Beta-adrenergic blocking agent, DrugG, Central antihypertensive drug, DrugH, Diuretic, DrugS, Single-Pill combination.

(P=0.004). Cardiovascular, general, and geriatric departments had high first-line drug usage (>98%), whereas non-specialized departments had the lowest usage (76.03%) and the steepest decline (APC=−1.07%, P=0.005). The declining trends in most departments, except general medicine, were statistically significant (P<0.05) (Table 3).

Trend and Subgroup Analysis of the Non-First-Line Antihypertensive Drugs Use

According to Table 4, the overall proportion of non-first-line antihypertensive prescriptions was 2.53%, showing an increasing trend (APC=27.69%, P=0.003). Subgroup analysis revealed gender differences, with higher usage among

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Character	Prevalence Rate	RR (95% CI)	*P*
Year	19.10	1.085 (1.074, 1.096)	<0.001
sex			
female	16.72	Reference	
male	21.48	1.185 (1.129, 1.243)	<0.001
Age (years)			
65~74	15.65	Reference	
75~84	20.08	1.288 (1.221, 1.359)	<0.001
>=85	29.28	1.641 (1.540, 1.749)	<0.001
Region			
South	14.42	Reference	
North	27.73	1.613 (1.535, 1.695)	<0.001
Hospital Grade			
level1	46.52	Reference	
level2	13.97	0.515 (0.445, 0.596)	<0.001
level3	18.69	0.599 (0.540, 0.666)	<0.001
Clinical Department			
OD	22.65	Reference	
GP	26.27	0.983 (0.896, 1.078)	0.711
CD	9.39	0.468 (0.439, 0.499)	<0.001
GD	37.94	1.453 (1.354, 1.560)	<0.001

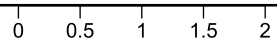

Figure 2 Poisson Regression Analysis of Factors Influencing Contraindicated Medication Prescriptions in Elderly Hypertensive Patients in China (2016–2023).
Notes: Prevalence Rate: The number of cases of contraindicated medication prescriptions per 10,000 cases of elderly hypertensive patients. RR: Relative risk. Reference Groups: Female for sex, ages 65–74 for age group, South for region, level 1 for hospital grade, and OD for clinical department.
Abbreviations: OD, Other Departments; GP, General Practice; CD, Cardiology Department; GD, Geriatrics Department.

males compared to females (3.74% vs 1.32%), and a more obvious increase (APC=31.48% vs 17.96%). The proportion varied across different age groups, with the 65–74 age group showing the fastest increase (APC=29.78%, *P*=0.002). Southern regions had higher usage rates than northern regions (3.01% vs 1.66%) and a faster increase (APC=34.02% vs 12.92%). Higher-level hospitals had lower usage of non-first-line drugs but faster increases, with tertiary hospitals showing an APC of 28.92% (*P*=0.003). Cardiovascular, general, and geriatric departments had low usage of non-first-line drugs (<2%), whereas other departments had the highest usage (3.70%) and the steepest increase (APC=31.99%, *P*=0.005). The increasing trends in most departments, except general medicine, were statistically significant (*P*<0.05).

Table 2 Prescription Rates and Trends of Antihypertensive Medications in Elderly Hypertensive Patients in China (2016–2023)

Drug Category	PR (%) (n=3,640,453)	First-line Agents	Annual Change	
			APC(95% CI)	*P for Trend*
CCB	49.75	Y	−3.46 (−5.79 ~ −1.13)	0.011
β-Blocker	32.47	Y	1.48 (0.23 ~ 2.74)	0.028
ARB	26.88	Y	−7.79(−10.88~-4.69)	<0.001
Diuretic	8.44	Y	11.41 (4.67~ 18.15)	0.006
ACEI	6.19	Y	−12.95 (−17.30~ −8.60)	<0.001
SPC	19.84	Y	−3.86 (−6.69 ~ −1.02)	0.016
αβ-Blocker	2.56	N	10.16 (7.18 ~ 13.15)	<0.001
α-Blocker	2.56	N	20.47 (9.39 ~ 31.56)	0.004
CADs	0.24	N	−14.36 (−20.28 ~ −8.44)	<0.001

Notes: PR: Prescription Rate, the percentage of prescriptions for each drug category among elderly hypertensive patients; First-line Agents indicates whether the drug category is considered a first-line treatment option (Y) or not (N); *P* for trend: *P* value for the trend analysis.
Abbreviations: CCB, Calcium Channel Blocker; *β*-blocker, Beta-adrenergic blocking agent; ARB, Angiotensin Receptor Blocker; ACEI, Angiotensin Converting Enzyme Inhibitor; SPC, Single-Pill combination; *αβ*-Blocker, Alpha-Beta adrenergic blocking agent; *α*-Blocker, Alpha-adrenergic blocking agent; CAD, Central antihypertensive drug; APC, Annual Percentage Change.

Table 3 Proportional Trends of First-Line Antihypertensive Drug Prescriptions in Elderly Hypertensive Patients in China (2016–2023)

Character	PR (%)	APC (95% CI)	*P for trend*
Total	97.47	−0.66 (−1.01, −0.31)	0.004
Sex			
Male	96.26	−1.06 (−1.65, −0.46)	0.005
Female	98.68	−0.25 (−0.38, −0.12)	0.003
Age (years)			
65~74	97.32	−0.71 (−1.08, −0.34)	0.003
75~84	97.64	−0.61 (−0.96, −0.27)	0.005
≥85	97.62	−0.57 (−0.86, −0.27)	0.003
Region			
Northern	98.34	−0.23 (−0.39, −0.07)	0.013
Southern	96.99	−0.88 (−1.33, −0.43)	0.003
Hospital Grade			
Level 1	98.52	−0.42 (−0.67, −0.17)	0.003
Level 2	98.05	−0.43 (−0.60, −0.27)	<0.001
Level 3	97.39	−0.69 (−1.06, −0.32)	0.004
Clinical Department			
GP	98.40	−0.17 (−0.35, 0.01)	0.063
CD	98.68	−0.27 (−0.40, −0.13)	0.003
GD	98.42	−0.36 (−0.56, −0.16)	0.005
OD	96.30	−1.07 (−1.66, −0.47)	0.005

Notes: PR: Prescription Rate, the percentage of first-line antihypertensive drug prescriptions; APC: Annual Percentage Change with 95% Confidence Intervals (CI); *P* for trend: *P* value for the trend analysis; Hospital grade is based on the Chinese hospital grading system, where Level 1 indicates primary hospitals, Level 2 indicates secondary hospitals, and Level 3 indicates tertiary hospitals.

Abbreviations: GP, General Practice; CD, Cardiology Department; GD, Geriatrics Department; OD, Other Departments.

Trends and Influencing Factors of Irrational Drug Use

Table 5 shows Poisson regression results for trends in irrational drug use among older adults with hypertension from 2016 to 2023. Irrational drug use included contraindicated medication and inappropriate combination medication, with prevalence rates of 1.91‰ and 7.408‰, respectively, yielding an overall irrational drug use rate of 9.318‰. In the unadjusted model (Model1), the prevalence of contraindicated medication increased (RR=1.077, 95% CI: 1.066–1.088, $P<0.001$), while inappropriate combination medication and total irrational drug use prevalence declined (RR=0.952, 95% CI: 0.947–0.957, $P<0.001$; RR=0.976, 95% CI: 0.971–0.980, $P<0.001$). These trends persisted in models adjusting for gender, age (Model2),

Table 4 Proportional Trends of Non-First-Line Antihypertensive Drug Prescriptions in Elderly Hypertensive Patients in China (2016–2023)

Character	PR (%)	APC (95% CI)	*P for Trend*
Total	2.53	27.69 (13.36, 42.02)	0.003
Sex			
Male	3.74	31.48 (13.35, 49.61)	0.005
Female	1.32	17.96 (11.04, 24.89)	0.001
Age (years)			
65~74	2.68	29.78 (15.41, 44.16)	0.002
75~84	2.36	25.56 (10.74, 40.38)	0.006
≥85	2.38	25.57 (13.09, 38.05)	0.002

(*Continued*)

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Table 4 (Continued).

Character	PR (%)	APC (95% CI)	*P for Trend*
Region			
Northern	1.66	12.92 (2.81, 23.02)	0.020
Southern	3.01	34.02 (18.91, 49.14)	0.002
Hospital Grade			
Level 1	1.48	18.52 (9.40, 27.64)	0.001
Level 2	1.95	22.28 (12.05, 32.52)	<0.001
Level 3	2.61	28.92 (13.90, 43.94)	0.003
Clinical Department			
GP	1.60	9.44 (−2.15, 21.03)	0.093
CD	1.32	19.80 (13.04, 26.57)	<0.001
GD	1.58	21.11 (9.90, 32.32)	0.004
OD	3.70	31.99 (13.92, 50.06)	0.005

Notes: PR: Prescription Rate, the percentage of first-line antihypertensive drug prescriptions; APC: Annual Percentage Change with 95% Confidence Intervals (CI); *P* for trend: *P* value for the trend analysis; Hospital grade is based on the Chinese hospital grading system, where Level 1 indicates primary hospitals, Level 2 indicates secondary hospitals, and Level 3 indicates tertiary hospitals.
Abbreviations: GP, General Practice; CD, Cardiology Department; GD, Geriatrics Department; OD, Other Departments.

Table 5 Poisson Regression Analysis of Inappropriate Medication Use Trends in Elderly Hypertensive Patients in China (2016–2023)

Events	Prevalence Rate	Model1		Model2		Model3	
		RR (95% CI)	*P for Trend*	RR (95% CI)	*P for Trend*	RR (95% CI)	*P for Trend*
D1	19.10	1.077 (1.066, 1.088)	<0.001	1.079 (1.068, 1.090)	<0.001	1.085 (1.074, 1.096)	<0.001
D2	74.08	0.952 (0.947, 0.957)	<0.001	0.953 (0.948, 0.958)	<0.001	0.961 (0.956, 0.966)	<0.001
D3	93.18	0.976 (0.971, 0.980)	<0.001	0.977 (0.973, 0.982)	<0.001	0.984 (0.980, 0.989)	<0.001

Notes: Prevalence Rate: The number of events per 10,000 cases of elderly hypertensive patients; Model1: unadjusted; Model2 additionally adjusted for gender and age; Model3 additionally adjusted for prescription region, hospital grade, and clinical department; D1: Contraindicated Medication Prescriptions; D2: Medication duplication; D3: Inappropriate medication use, including both D1 and D2; RR: Risk Relative risk with 95% confidence intervals (CI); *P* for trend: *P* value for the trend analysis.

and additional factors like region, hospital level, and clinical department (Model3). Among them, the RRs of the prevalence of contraindication medication in Model2 and Model3 were 1.079 (95% CI: 1.068–1.090) and 1.085 (95% CI: 1.074–1.096), respectively, both showing an increasing trend year by year ($P<0.001$). The RRs of inappropriate combination medication and total irrational medication in Model3 were 0.961 (95% CI: 0.956–0.966) and 0.984 (95% CI: 0.980–0.989), both showing a continuous downward trend, and the trend change was statistically significant ($P<0.001$).

Trends and Influencing Factors of Contraindicated Medications

To investigate trends and influencing factors of contraindicated medication among elderly hypertensive patients in China from 2016 to 2023, this study employed a Poisson regression model to analyze the association between the prevalence of contraindicated medication and factors such as patient gender, age, prescription region, hospital grade, and clinical department (Figure 2). After adjusting for these factors, the prevalence of contraindicated medication showed a significant upward trend during the study period ($P<0.001$).

Significant differences in the prevalence of contraindicated medication were observed among patients with varying demographic and clinical characteristics. Compared to females, male patients had a significantly higher prevalence (RR = 1.185, 95% CI: 1.129–1.243, $P<0.001$). The prevalence in the ≥85-year-old age group was 1.641 times higher than the group aged 65–74 years old (95% CI: 1.540–1.749, $P<0.001$). Patients in northern regions had an prevalence 1.613 times higher than in southern regions (95% CI: 1.535–1.695, $P<0.001$). Hospital grade was negatively correlated with the

prevalence of contraindicated medication. Compared to primary-level hospitals, the RRs for secondary and tertiary hospitals were 0.515 (95% CI: 0.445–0.596) and 0.599 (95% CI: 0.540–0.666), respectively, with statistically significant differences ($P<0.001$). Additionally, the risk of prescribing contraindicated medications varied across departments. Compared to other non-specialized departments, geriatrics had the highest risk (RR = 1.453, 95% CI: 1.354–1.560, $P<0.001$), while cardiology had a lower risk (RR = 0.468, 95% CI: 0.439–0.499, $P<0.001$).

Discussion

This study investigated the overall situation, trend changes, and influencing factors of antihypertensive medication use among elderly hypertensive patients in China from 2016 to 2023. Our main findings include: CCBs are the most widely used antihypertensive drugs, followed by β-blockers, ARBs, SPCs, and diuretics. Among these, the usage rates of CCBs, ARBs, and SPCs show a decreasing trend, while the usage rates of β-blockers and diuretics are on the rise. During the study period, the prescription proportion of first-line antihypertensive drugs generally remained at a high level but also showed a slight decline. The prevalence of repetitive medication and overall irrational medication showed a decreasing trend, whereas the prevalence of contraindicated medication showed an increasing trend. Males, advanced age, northern regions, primary hospitals, and geriatric departments had a higher risk of contraindicated medication.

Our findings on the most used antihypertensive drug classes are consistent with previous studies in China and other Asian countries.[20,21] The high prescription rate of CCBs may be related to their additional benefit in preventing strokes in Asian populations and their good tolerability.[22] Although the prescription rates of both ACEIs and ARBs showed a decreasing trend, the decline in ACEIs was more significant, which may be related to ACEIs being more likely to cause persistent dry cough and angioedema compared to ARBs.[23,24] The increase in the use of β-blockers may be related to their unique role in the treatment of coronary heart disease.[25] The greater use of diuretics can be attributed to the fact that complex drug regimens, necessary for achieving lower blood pressure targets, benefit significantly from the inclusion of diuretics, as these agents enhance the blood pressure-lowering effects of virtually every other non-diuretic drug class.[4,5] Additionally, SPCs were the fourth most used class of antihypertensive drugs in this study. Although the usage rate of SPC remained stable from 2016 to 2020, it decreased after 2021. Numerous studies have shown that SPCs can significantly improve patient compliance and blood pressure control rates compared to monotherapy.[26–28] The Chinese guidelines for the prevention and treatment of hypertension also recommend SPCs as the preferred combination therapy.[4] Therefore, the results of this study also suggest that the future research and practice of SPC rational application should be strengthened, varieties and formulations of SPCs suitable for elderly patients should be expanded, and the education on the application of SPCs for both doctors and patients should be enhanced, to improve patient access and acceptance of SPCs.

Encouragingly, the overall usage rate of first-line antihypertensive drugs remained at a high level, reflecting that clinical practice has generally followed the recommendations of existing guidelines. However, the slight downward trend is still noteworthy and suggests that further educational and intervention measures are necessary.[29] Moreover, the differences in the usage rates of first-line antihypertensive drugs among different subgroups highlight the importance of targeted intervention strategies in specific populations and clinical settings to improve prescription quality. Non-specialty treatment departments had the lowest and fastest-declining usage rates of first-line drugs, which may be related to non-specialist doctors' relatively lower emphasis on hypertension management and insufficient mastery and implementation of evidence-based guidelines.[30,31] Improving non-specialist doctors' awareness and capabilities in standardized diagnosis and treatment of elderly hypertension is an important aspect of improving the use of first-line antihypertensive drugs.[31] Clinical pharmacists can leverage their professional expertise to assist non-specialist doctors in drug evaluation and optimization, providing professional pharmaceutical guidance and decision support.[32]

Another important finding of this study is that the issue of irrational medication among elderly hypertensive patients in China still warrants attention. Although the overall rate of irrational medication showed a declining trend, the rate of contraindicated medication increased, highlighting potential risks and challenges in medication safety for elderly hypertensive patients. This finding fills gaps in existing literature and provides new evidence and insights for developing and implementing targeted interventions.[33] The study identified key risk factors for contraindicated medication among elderly hypertensive patients, including male gender, age ≥85 years, residence in northern regions, and receiving treatment outside cardiology specialities, particularly in geriatrics. These findings offer critical clues and evidence for

formulating and implementing targeted medication safety interventions. For male and elderly patients, special attention should be given to evaluating contraindications during prescription decision-making. Clinical pharmacists can also focus on evaluating this patient population. The significantly higher risk of contraindicated medication in northern regions compared to southern regions suggests potential disparities and imbalances in medication regulation and practice between regions. Additionally, primary healthcare institutions exhibit the highest risk of contraindicated medication, which might be due to weaknesses in medication management and staff training.[34] Clinical departments represent another key influencing factor for contraindicated medication. Geriatrics departments have the highest risk, which may be related to their patient population primarily consisting of older adults with multiple comorbidities and polypharmacy, leading to more limitations in medication selection.[35,36] For high-risk departments such as geriatrics, it is recommended to involve clinical pharmacists in medication therapy management. They can assist in evaluating the appropriateness of medications for elderly patients and identifying and addressing potential issues with contraindicated medications.[37]

In summary, this study included a national multicenter sample of elderly hypertensive patients and examined the use of antihypertensive medications over an 8-year period. It investigated the prevalence and risk factors of irrational medication in this vulnerable population, providing an important reference for future research and practice in rational medication use. However, there are some limitations. Firstly, this study used a cross-sectional design, and the data were derived from hospital electronic medical record systems, which did not provide patient outcome information, such as blood pressure control levels and the occurrence of cardiovascular events, which limited our ability to assess the clinical impact of different prescribing patterns on patient outcomes. Future research should consider including patient outcome information for a comprehensive evaluation of the clinical impact and significance of prescribing behaviors. Secondly, the study data were based on patients' medication prescriptions and lacked complete clinical information, which may have underestimated the prevalence of irrational medication. Lastly, the survey data were sourced from the electronic medical record systems of hospitals in 9 cities across the country. Although the cities covered different geographical locations and socioeconomic levels, rural area hospitals were not included. Due to the differences in the distribution of medical resources and the level of healthcare services between urban and rural areas, the prescribing behavior in rural area hospitals may differ from that in urban hospitals.[38] Therefore, there may be issues of insufficient representativeness when directly extrapolating the results to rural areas. Despite these limitations, the study still provides an important reference and basis for optimizing the medication treatment of elderly hypertensive patients.

Conclusion

This study revealed that CCB, β-blockers, and ARB were the most used drugs. While the overall usage rate of first-line antihypertensive medications remained high, there was a slight decline over time. During the study period, the prevalence of irrational medication showed a decreasing trend, but the risk of contraindicated medication increased. Higher risks were observed in male patients, older age groups, northern regions, primary healthcare institutions, and geriatric departments. The results provide insights for optimizing antihypertensive therapy in elderly patients. Future efforts should focus on targeted education and intervention strategies, strengthening collaboration between pharmacy services and clinical specialties, and improving medication management practices, to enhance the quality of pharmacological treatment for elderly hypertensive patients.

Data Sharing Statement

The original contributions presented in this study are included in the article/supplementary material, and further inquiries can be directed to the corresponding authors.

Ethics Approval and Informed Consent

This study has been approved by the Ethics Committee of the First Affiliated Hospital of Zhejiang University School of Medicine: Expedition review No. 1538 in 2024. The requirement for informed consent was waived by the ethics committee for this study, in accordance with national legislation and institutional regulations. The patients' personal information was confidential to the researchers, and the study was conducted in compliance with the Declaration of Helsinki.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis, and interpretation, or in all these areas; took part in drafting, revised or critically reviewed the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

The authors report no conflicts of interest regarding the content of this article.

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