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Blood pressure control and antihypertensive treatment in Swiss general practice: a cross-sectional study using routine data

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Summary

AIMS OF THE STUDY: Arterial hypertension is a major global health risk. Global surveys indicate that only half of patients with arterial hypertension receive pharmacotherapy, and only a quarter achieve the primary blood pressure target recommended by guidelines. This study aimed to evaluate the achievement of the primary blood pressure target in Swiss general practice, provide insights into arterial hypertension treatment, and identify factors associated with achieving this goal.

METHODS: This cross-sectional study utilised data from a large Swiss primary care database. Patients with arterial hypertension, aged ≥18 years, who underwent blood pressure monitoring in 2021 were included. The primary observation was blood pressure control, defined as the achievement of the primary blood pressure target of systolic blood pressure <140 mm Hg and diastolic blood pressure <90 mm Hg. Demographic data from physicians and patients, blood pressure measurements, comorbidities, cardiovascular risk factors, and pharmacotherapy were collected, and arterial hypertension stages were calculated. Unadjusted and multivariable-adjusted mixed logistic regression models were used to identify factors associated with blood pressure control.

RESULTS: A total of 49,290 patients were included, of whom 23,933 (48.6%) were female. The median patient age was 71 years (interquartile range 61–80). Blood pressure control was observed in 23,022 patients (46.7%), and 36,692 patients (74.4%) had an antihypertensive pharmacotherapy prescription. In multivariable analysis, blood pressure control was positively associated with arterial hypertension stage, antihypertensive pharmacotherapy, the intensity of blood pressure monitoring, and the number of blood pressure-increasing drugs, but negatively associated with a long-standing arterial hypertension, female sex, and old age.

CONCLUSIONS: While general practitioners appear to consider arterial hypertension stages in their treatment strategies, there is still room for improvement in arterial hypertension care by prescribing pharmacotherapy, especially in patients with long-standing arterial hypertension, female sex and old age.

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Introduction

Arterial hypertension affects approximately 10% of the global population and is the leading cause of cardiovascular diseases and premature mortality worldwide [1, 2]. Along with lifestyle modifications, lowering blood pressure with pharmacotherapy is the mainstay of arterial hypertension treatment and is supported by strong evidence demonstrating its beneficial effects on key outcomes [3, 4]. Numerous trials have evaluated the optimal treatment goals for pharmacotherapy in arterial hypertension, based on blood pressure levels and patient characteristics [4–6]. However, the evidence is less clear for older patients [7–9]. Given the potential side effects of arterial hypertension pharmacotherapy and the risk of treatment discontinuation, the 2018 European Society of Cardiology (ESC) / European Society of Hypertension (ESH) guidelines for the management of arterial hypertension recommend a stepwise approach to achieve blood pressure targets: a primary blood pressure goal, and for patients who tolerate treatment well, a secondary goal [10].

Achieving the primary blood pressure target of systolic blood pressure <140 mm Hg and diastolic blood pressure <90 mm Hg is commonly referred to as blood pressure control [11]. The proportion of arterial hypertension patients with blood pressure control is frequently used as a performance indicator for the quality of hypertension care [11]. Despite this, global surveys continue to show substantial evidence-to-practice gaps, with only half of the patients with arterial hypertension receiving pharmacotherapy and only a quarter with blood pressure control [12,

ABBREVIATIONS

ACEI:	angiotensin-converting enzyme inhibitor
ARB:	angiotensin receptor blocker
CCB:	calcium channel blocker
ESC:	European Society of Cardiology
ESH:	European Society of Hypertension

13]. In Switzerland, a 2009 study reported blood pressure control in approximately 50% of patients receiving antihypertensive pharmacotherapy [14]. However, blood pressure control is influenced by both patient- and physician-related factors, which need further exploration as potential enhancers or detractors. While limited data exist on physician characteristics as predictors of blood pressure control, all relevant variables should be assessed to identify potential targets for interventions aimed at improving the quality of arterial hypertension care.

Therefore, to consolidate the epidemiological basis for better arterial hypertension management, this study primarily seeks to provide updated insights into blood pressure control in Swiss general practice and, secondarily, to identify factors associated with blood pressure control, including arterial hypertension stage, pharmacotherapy, and patient and physician characteristics.

Materials and methods

Study design, setting, participants and ethics statement

We conducted a cross-sectional study based on data from Family Medicine Research using Electronic Medical Records (FIRE), a large Swiss general practice database established in 2009 [15]. The database currently includes data from 750 individual general practitioners and over 12 million consultation records, including administrative information, laboratory test results, vital sign measurements, and pharmacotherapy prescriptions. For this study, we included general practitioners who contributed data in 2021. Patient inclusion criteria were as follows: arterial hypertension diagnosis before 2021, age ≥18 years, and blood pressure monitoring during 2021 (i.e., at least one office blood pressure measurement recorded in 2021). Arterial hypertension was defined as at least one of the following at any time during the patient's medical history: (1) antihypertensive drug therapy as defined by the Swiss Pharmaceutical Cost Group [16]; (2) a general practitioner-assigned reason for encounter codes K85, K86, or K87 of the International Classification of Primary Care, 2nd edition (ICPC-2) [17]; or (3) at least two office-based blood pressure measurements with systolic blood pressure ≥140 mm Hg or diastolic blood pressure ≥90 mm Hg each, with the second confirmatory measurement collected within 7 days to 6 months of the first, or a single blood pressure measurement of systolic blood pressure ≥180 mm Hg or diastolic blood pressure ≥110 mm Hg without a second confirmatory measurement [10, 18].

The local ethics committee of the Canton of Zurich waived approval for this study as it was based on anonymised data and thus fell outside the scope of the Swiss Federal Act on Research Involving Human Beings (BASEC-Nr. Req2017–00797).

Database query and definitions

For each patient, the last available blood pressure measurement in 2021 was defined as the index measurement. The most recent information prior to the index measurement was used to determine sex, age (continuous and categorical variables: <30, 30–64, 65–80, >80 years, or <65, ≥65 years as appropriate), and comorbidities (obesity, chronic kidney disease, dyslipidaemia, diabetes mellitus, and cardiovascular disease, as defined in appendix table S1, according to established methods [19, 20]). To capture active antihypertensive pharmacotherapy at the time of the index measurement, we queried all antihypertensive medications documented in the 5 years preceding the index measurement that had not been subsequently discontinued, based on their Anatomical Therapeutic Chemical (ATC) codes [21]. Data on potentially blood pressure-increasing pharmacotherapy were considered from 3 months prior to the index measurement.

Antihypertensive drugs were divided into the following classes: angiotensin-converting enzyme inhibitors (ACEI), angiotensin II receptor blockers (ARB), beta-blockers, calcium channel blockers (CCB), diuretics, and other antihypertensives (list of ATC codes is provided in appendix table S2). The following were classified as blood pressure-increasing drugs: antidepressants, oestrogens or testosterone, stimulants, anti-obesity agents, decongestants, antipsychotics, and systemic preparations of non-steroidal anti-inflammatory drugs (NSAIDs) and steroids (table S2) [22]. For combination drugs, each antihypertensive/blood pressure-increasing component was counted towards the total number of prescribed medications. Antihypertensive treatment intensity was classified as monotherapy, dual therapy, triple therapy, or more than three antihypertensive substances.

Arterial hypertension stages 1 to 3 were determined using the definitions outlined in the 2018 ESC guidelines for the management of arterial hypertension [10] and adapted to the variables available in FIRE (table S3 in the appendix). According to these guidelines [10], arterial hypertension was classified as *controlled* when the primary blood pressure goal was achieved (systolic blood pressure [SBP] <140 mm Hg and diastolic blood pressure [DBP] <90 mm Hg), with further sub-classification based on the achievement of the secondary blood pressure goal (age <65 years: SBP <130 mm Hg and DBP <80 mm Hg; age ≥65 years: SBP <140 mm Hg and DBP <80 mm Hg). Arterial hypertension was classified as *uncontrolled* when the primary blood pressure goal was not achieved (SBP ≥140 mm Hg or DBP ≥90 mm Hg), with further sub-classification into *uncontrolled systolic* (SBP ≥140 mm Hg and DBP <90 mm Hg), *uncontrolled diastolic* (SBP <140 mm Hg and DBP ≥90 mm Hg) or *uncontrolled combined systolic-diastolic* (SBP ≥140 mm Hg and DBP ≥90 mm Hg). Patients with uncontrolled arterial hypertension were further classified as having *resistant* arterial hypertension if they were taking antihypertensive medications from three or more different drug classes at the time of the index measurement, including a diuretic.

The general practitioner characteristics collected were: age (both continuous and categorical variables: ≤50, >50 years), sex, type of practice organisation (single, double, or group practice), working position (employee, self-employed), workload (expressed as percentage of full-time equivalent) in the practice, and the practice's postal code, which was used to identify the practice's location area (urban, suburban, rural) according to the Eurostat Degree of Urbanisation index for Switzerland [23].

Observations

The primary observation was blood pressure control, defined as the achievement of the primary blood pressure goal (yes, no). Secondary observations included the achievement of the secondary blood pressure goal (yes, no) and arterial hypertension pharmacotherapy (categorical), as defined above in terms of drug classes and treatment intensity.

We considered the following variables as potential factors associated with blood pressure control: *(3a) patient-related*: age (categorical: <65, ≥65 years), sex, arterial hypertension stage, pharmacotherapy for arterial hypertension (yes, no), number of blood pressure-increasing drugs used (categorical: 0, 1, ≥2), long-lasting arterial hypertension diagnosis (≥5 years: yes, no), intensity of blood pressure monitoring in 2021 (categorical: ≤5, >5 measurements); *(3b) general practitioner-related*: age (categorical), sex, practice organisation, working position and workload, and practice location area.

Statistical analysis

Summary statistics were presented as numbers (n) and percentages (%) for categorical and binary variables, and as mean and standard deviation (SD) or median and interquartile range (IQR), as appropriate, for continuous variables. An available case analysis was performed. Blood pressure control and the achievement of the secondary blood pressure goal were presented as proportions of all included patients and within each arterial hypertension stage and age group, with the latter stratification represented graphically. Descriptive statistics for arterial hypertension pharmacotherapy were reported overall and stratified by patients with and without blood pressure control. To identify factors associated with blood pressure control, both unadjusted (univariable) and multivariable-adjusted mixed logistic regression models were used. Random intercept effects were included at the general practitioner level to account for correlations between patients cared for by the same general practitioner. Predictors for the multivariable final model were selected using a stepwise backward approach, starting from a full model that included all variables with $p < 0.2$ in univariable analyses. Multicollinearity was assessed using the variance inflation factor (VIF), generalised for logistic regression, for each predictor.

The results of the regression analyses were reported as odds ratios (OR) with 95% confidence intervals (CI). The final model results were represented in an odds ratio (OR) plot.

Test results were considered statistically significant at $p \leq 0.05$. All analyses were conducted using the R statistical package, version 4.1.0 [24], with additional packages: *dplyr* version 1.1.2, *tidyverse* version 2.0.0, *tableone* version 0.13.2, *ggplot2* version 3.4.2, *finalfit* version 1.0.6, *ggVennDiagram* version 1.2.2.

Results

Patient characteristics

We identified 458,240 eligible patients in the FIRE database, with 49,290 meeting the inclusion criteria (figures S1–S2 in the appendix, for the full inclusion process and identification criteria). Patient characteristics, overall and stratified by arterial hypertension stage, are shown in table 1. Of the total patient cohort, 23,933 (48.6%) were women. The median patient age was 71 years (IQR 61–80). The most prevalent comorbidities were dyslipidaemia, obesity, and cardiovascular disease, affecting 22,764 (46.2%), 14,582 (29.6%), and 13,631 (27.7%) patients, respectively.

Blood pressure control

The average index measurement was 139.9 mm Hg (SD 18.7) for systolic blood pressure and 81.9 mm Hg (SD 11.4) for diastolic blood pressure (systolic and diastolic blood pressure distributions are shown in figure S3–S4 in the appendix). Overall, blood pressure control was observed in 23,022 patients (46.7%), while the secondary blood pressure goal was met in 12,411 patients (25.2%). The percentages increased with the arterial hypertension stage, with blood pressure control rates of 42.7%, 49.9%, and 51.1%, and achievement of the secondary goal in 19.0%, 28.7%, and 33.1% of cases in arterial hypertension stages 1 to 3, respectively. Blood pressure control and the achievement of the secondary blood pressure goal, stratified by arterial hypertension stage and age group, are shown in table 1 and figure 1, respectively.

Antihypertensive pharmacotherapy

Overall, 36,692 patients (74.4%) had active antihypertensive prescriptions at the time of the blood pressure index measurement. Among the remaining 12,598 patients (25.6%), 6092 (12.4%) had never been treated, and 6506 (13.2%) had previously been prescribed antihypertensive pharmacotherapy, which was later discontinued. Regarding treatment intensity, 12,820 patients (26.0%) were prescribed monotherapy, 11,937 (24.2%) were prescribed dual therapy, 7771 (15.8%) received triple therapy, and 4164 (8.4%) received more than three antihypertensive substances.

The most frequently prescribed drug class overall was ARB, prescribed to 17,102 patients (34.7%), followed by beta-blockers to 15,756 patients (32.0%), and ACEI to 14,956 patients (30.3%). The distribution of individual drug classes across monotherapy, dual therapy, triple therapy, and four or more therapies is shown in figure 2.

Table 2 describes the prescribed antihypertensive pharmacotherapies overall and stratified by blood pressure control status (ATC codes listed in table S4 in the appendix).

The most frequently prescribed combinations in patients who received dual therapy were ARB + diuretic and ACEI + beta-blocker (prescribed to 4.5% and 3.7% of patients, respectively). The most prescribed triple therapies were ARB + CCB + diuretic (3.9%) and ARB + beta-blocker + diuretic (2.1%). Among patients on dual or triple antihypertensive therapies, 10,958 (22.2% of all patients) were prescribed fixed-dose combinations.

Factors associated with blood pressure control

The final adjusted regression model, shown in figure 3, revealed that blood pressure control was positively associat-

ed with arterial hypertension stage. Compared to stage 1 patients, stage 2 patients had an OR of 1.38 (CI 1.31–1.45), and stage 3 patients had an OR of 1.46 (CI 1.39–1.54). Other factors positively associated with blood pressure control included the intensity of blood pressure monitoring in 2021, with an OR of 1.35 (CI 1.23–1.48) for patients with more than five measurements compared to those with fewer. Treatment with blood pressure-increasing drugs was also positively associated with blood pressure control, with an OR of 1.06 (CI 1.01–1.12) for one blood pressure-increasing drug prescribed, and 1.14 (CI 1.06–1.23) for more than one blood pressure-increasing drug, compared to no blood pressure-increasing drugs. Conversely, blood pressure control was negatively associated with female sex (OR 0.86, CI 0.83–0.90) compared to male sex, patient age ≥65 years (OR 0.88, CI 0.84–0.91) compared to younger age, lack of antihypertensive pharmacotherapy (OR 0.86, CI 0.82–0.91) compared to being on antihypertensive pharmacotherapy, and a long-lasting diagnosis (OR 0.91, CI 0.86–0.96) compared to a diagnosis within the last five years. Further results are provided in table S5 in the appendix.

Discussion

Main findings

In this study, we aimed to improve the understanding of blood pressure control and pharmacotherapy in patients with arterial hypertension treated in Swiss general practice. We found nearly half of the patients with blood pressure control, and one in four met the secondary blood pressure goal. Three-quarters of patients with arterial hypertension received antihypertensive pharmacotherapy, predominantly in the form of monotherapy or dual therapy. Blood pressure control was positively associated with arterial hypertension stage, the intensity of blood pressure monitoring, and the number of blood pressure-increasing drugs, but negatively associated with the absence of antihypertensive pharmacotherapy, long-standing arterial hypertension diagnosis, female sex, and older age.

Patient selection and sample representativeness

We identified patients with arterial hypertension from a large Swiss primary care database and found a prevalence of approximately 22%. This figure aligns closely with the prevalence reported by Godwin et al., who used highly comparable methods in a Canadian general practice-based study [25]. Another study estimated the prevalence of arterial hypertension in Swiss general practice to be 20% [26], supporting the validity of our data. The patients in our study were, on average, more than five years older than those in similar studies using routine general practice data [14, 25, 27]. This difference may be due to our study design. First, unlike Godwin et al., we did not impose an upper age limit. Second, our study required patients to have undergone blood pressure monitoring in 2021, which may have selected older patients requiring more intensive follow-up.

Risk-stratified strategy for blood pressure control

In our study, 74% of patients received pharmacotherapy for arterial hypertension, and nearly 50% achieved blood pressure control, a figure consistent with studies from other high-income Western countries [13] and a previous Swiss

Table 1:
Demographic characteristics, comorbidities, and blood pressure characteristics at the index measurement of the 49,290 patients included, overall and stratified by arterial hypertension stage.

		Overall	Stage 1 arterial hypertension	Stage 2 arterial hypertension	Stage 3 arterial hypertension
Total, n (%)		**49,290**	**24,302 (49.3)**	**10,897 (22.1)**	**14,091 (28.6)**
Demographic characteristics	Sex* (female) n (%)	23,933 (48.6)	12,454 (51.2)	5533 (50.8)	5946 (42.2)
	Age (years) median (IQR)	71 (61–80)	66 (56–75)	74 (63–82)	77 (69–83)
Co-occurring conditions**, n (%)	Obesity	14,582 (29.6)	6327 (26.0)	4134 (37.9)	4121 (29.2)
	Chronic kidney disease	7695 (15.6)	511 (2.1)	3402 (31.3)	3782 (26.8)
	Chronic kidney disease grade 3 or higher	6300 (12.8)	0 (0.0)	3171 (29.1)	3129 (22.2)
	Dyslipidaemia	22,764 (46.2)	7427 (30.6)	5007 (45.9)	10,330 (73.3)
	History of smoking	909 (1.9)	347 (1.6)	174 (1.6)	388 (2.8)
	Diabetes mellitus	11,709 (23.8)	0 (0.0)	7063 (64.8)	4646 (33.0)
	Cardiovascular disease	13,631 (27.7)	0 (0.0)	0 (0.0)	13,631 (96.7)
	– Heart failure or atrial fibrillation	2027 (4.1)	0 (0.0)	0 (0.0)	2027 (14.4)
	– Obstructive atherosclerotic disease	12,444 (25.2)	0 (0.0)	0 (0.0)	12,444 (88.3)
	– Pulmonary heart disease	40 (0.0)	0 (0.0)	0 (0.0)	40 (0.0)
Blood pressure index measurement, mean (SD)	Systolic blood pressure (mm Hg)	139.9 (18.7)	141.1 (18.2)	139.1 (18.8)	138.6 (19.3)
	Diastolic blood pressure (mm Hg)	81.9 (11.4)	84.5 (10.9)	80.6 (11.1)	78.6 (11.3)
Blood pressure goal achievement, n (%)	Primary (i.e., blood pressure control)	23,022 (46.7)	10,379 (42.7)	5439 (49.9)	7204 (51.1)
	Secondary	12,411 (25.2)	4619 (19.0)	3127 (28.7)	4665 (33.1)
Uncontrolled arterial hypertension, n (%)	Isolated systolic	14,015 (28.4)	6201 (25.5)	3214 (29.5)	4600 (32.6)
	Isolated diastolic	2610 (5.3)	1698 (7.0)	485 (4.5)	427 (3.0)
	Combined systolic-diastolic	9643 (19.6)	6024 (24.8)	1759 (16.1)	1860 (13.2)
Resistant arterial hypertension		6326 (12.8)	2282 (9.4)	1464 (13.4)	2580 (18.3)

IQR: interquartile range

* Sex was missing for 2 patients, 1 with stage 2 arterial hypertension and 1 with stage 3 arterial hypertension.

** See definitions in appendix table S1.

study [14]. We found a positive association between arterial hypertension stage and blood pressure control, suggesting a risk-stratified treatment strategy. This represents a shift from previous evidence from Swiss general practice

Figure 1: Blood pressure control (BPC) (defined as achieving systolic <140 mm Hg and diastolic <90 mm Hg) and achievement of the secondary blood pressure goal (systolic <130 mm Hg, or <140 mm Hg if aged ≥65 years, and diastolic <80 mm Hg). Percentages are reported overall and stratified by patient age group. BP: blood pressure.

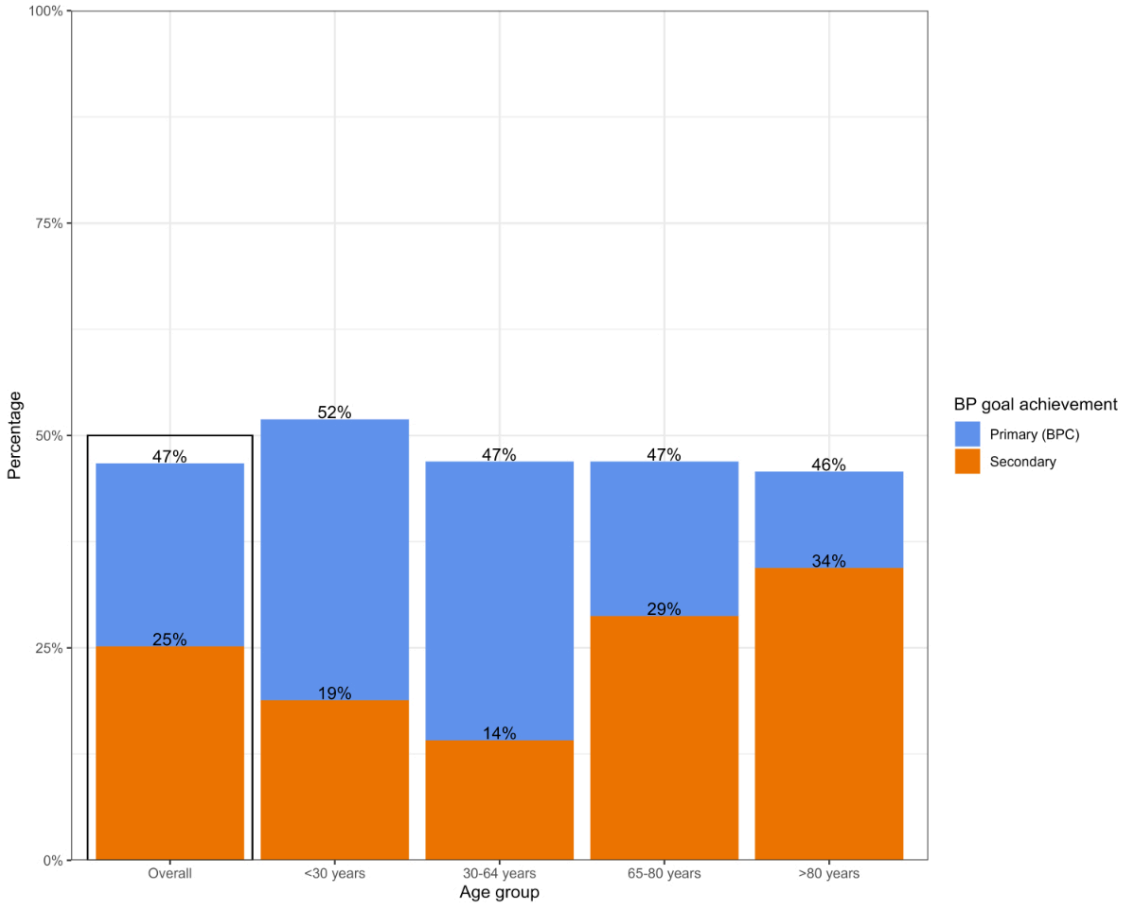
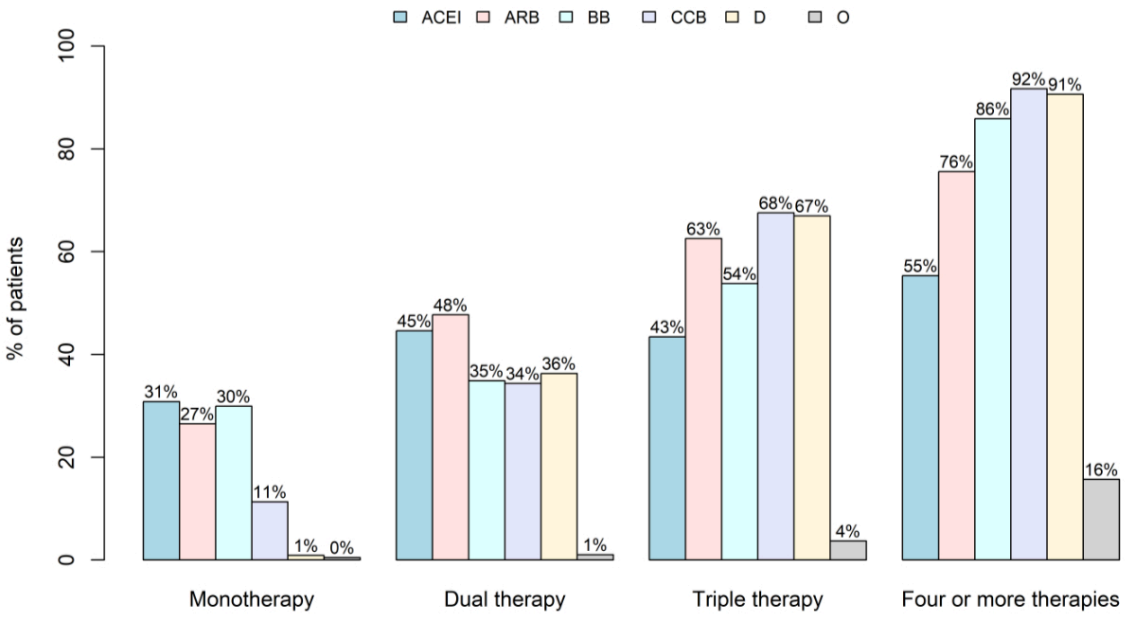


Figure 2: Drug classes by intensity of prescribed pharmacotherapy. Percentages are stratified across patients receiving monotherapy, dual therapy, triple therapy, and four or more therapies. ACEI: angiotensin-converting enzyme inhibitor; ARB: angiotensin receptor blocker; BB: beta-blocking agent; CCB: calcium channel blocker; D: diuretic; O: other antihypertensives.



in 2009, where a negative association was observed [14]. However, a risk-stratified approach was introduced in the 2013 ESC/ESH guidelines for arterial hypertension management and appears to have been adopted by Swiss general practitioners [28].

This risk-stratified approach was even more pronounced for the secondary blood pressure goal, with significant differences between groups: 19% of arterial hypertension stage 1 patients and 33% of arterial hypertension stage 3 patients achieved the secondary goal. However, it should

Table 2:
Numbers (percentages) of patients with (or without) specific antihypertensive pharmacotherapy at index measurement, overall and stratified by blood pressure control. Only drug combinations exceeding 1% within classes are shown.

		Overall	Patients with BPC	Patients without BPC
		n = 49,290	n = 23,022	n = 26,268
Pharmacotherapy				
Active* antihypertensive pharmacotherapy n (%)		36,692 (74.4)	17,483 (75.9)	19,209 (73.1)
No active antihypertensive pharmacotherapy n (%)		12,598 (25.6)	5539 (24.1)	7059 (26.9)
– Never prescribed		6092 (12.4)	2243 (9.7)	3849 (14.7)
– Prescribed but discontinued		6506 (13.2)	3296 (14.3)	3210 (12.2)
Type of antihypertensive pharmacotherapy				
Monotherapy n (%)	Overall	12,820 (26.0)	6181 (26.8)	6639 (25.3)
	ACEI	3953 (8.0)	1793 (7.8)	2160 (8.2)
	ARB	3399 (6.9)	1479 (6.4)	1920 (7.3)
	Beta-blocker	3836 (7.8)	2174 (9.4)	1662 (6.3)
	CCB	1453 (2.9)	650 (2.8)	803 (3.1)
	Diuretic	115 (0.2)	53 (0.2)	62 (0.2)
Dual therapy, n (%)	Overall	11,937 (24.2)	5693 (24.7)	6244 (23.8)
	All fixed-dose combinations	5779 (11.7)	2615 (11.4)	3164 (12.0)
	ARB + diuretic, total	2225 (4.5)	970 (4.2)	1255 (4.8)
	… as fixed-dose combination	2144 (4.3)	944 (4.1)	1200 (4.6)
	ARB + CCB, total	1791 (3.6)	760 (3.3)	1031 (3.9)
	… as fixed-dose combination	942 (1.9)	412 (1.8)	530 (2.0)
	ARB + beta-blocker, total	1298 (2.6)	645 (2.8)	653 (2.5)
	… as fixed-dose combination	–	–	–
	ACEI + CCB, total	1538 (3.1)	674 (2.9)	864 (3.3)
	… as fixed-dose combination	678 (1.4)	309 (1.3)	369 (1.4)
	ACEI + beta-blocker, total	1819 (3.7)	1081 (4.7)	738 (2.8)
	… as fixed-dose combination	–	–	–
	ACEI + diuretic, total	1607 (3.3)	733 (3.2)	874 (3.3)
	… as fixed-dose combination	1560 (3.2)	709 (3.1)	851 (3.2)
	CCB + beta-blocker, total	716 (1.5)	343 (1.5)	373 (1.4)
	… as fixed-dose combination	50 (0.1)	27 (0.1)	23 (0.1)
Triple therapy n (%)	Overall	7771 (15.8)	3718 (16.1)	4053 (15.4)
	As single drugs	2592 (5.3)	1281 (5.6)	1311 (5.0)
	Including a dual fixed-dose combination	3968 (8.1)	1849 (8.0)	2119 (8.1)
	As a triple fixed-dose combination	1211 (2.5)	588 (2.6)	623 (2.4)
	ARB + CCB + diuretic, total	1930 (3.9)	846 (3.7)	1084 (4.1)
	… including a dual fixed-dose combination	1010 (2.0)	420 (1.8)	590 (2.2)
	… as triple fixed-dose combination	890 (1.8)	416 (1.8)	474 (1.8)
	ARB + CCB + beta-blocker, total	992 (2.0)	456 (2.0)	536 (2.0)
	… including a dual fixed-dose combination	404 (0.8)	180 (0.8)	224 (0.9)
	… as triple fixed-dose combination	–	–	–
	ARB + beta-blocker + diuretic, total	1024 (2.1)	500 (2.2)	524 (2.0)
	… including a dual fixed-dose combination	977 (2.0)	480 (2.1)	497 (1.9)
	… as triple fixed-dose combination	–	–	–
	ACEI + CCB + diuretic, total	985 (2.0)	457 (2.0)	528 (2.0)
	… including a dual fixed-dose combination	631 (1.3)	270 (1.2)	361 (1.4)
	… as triple fixed-dose combination	321 (0.7)	172 (0.7)	149 (0.6)
	ACEI + CCB + beta-blocker, total	865 (1.8)	453 (2.0)	412 (1.6)
	… including a dual fixed-dose combination	275 (0.6)	157 (0.7)	118 (0.4)
	… as triple fixed-dose combination	–	–	–
	ACEI + beta-blocker + diuretic, total	731 (1.5)	381 (1.7)	350 (1.3)
	… including a dual fixed-dose combination	671 (1.4)	342 (1.5)	329 (1.3)
	… as triple fixed-dose combination	–	–	–
Four or more therapies n (%)		4164 (8.4)	1891 (8.2)	2273 (8.7)
Number of drugs median (IQR)		1 (0–2)	1 (1–2)	1 (0–2)

Abbreviations: ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; CCB, calcium channel blocker; IQR, interquartile range.

*Active pharmacotherapy included all antihypertensive drugs documented but not subsequently discontinued in the 5 years preceding the index measurement.

be noted that the secondary goal is age-dependent, and arterial hypertension stage 3 patients, who were on average six years older, had a more attainable target. Nevertheless, the stage 3 group also had double the proportion of patients with resistant hypertension compared to the stage 1 group (18% vs 9%), indicating further pharmaceutical escalation in response to higher risk.

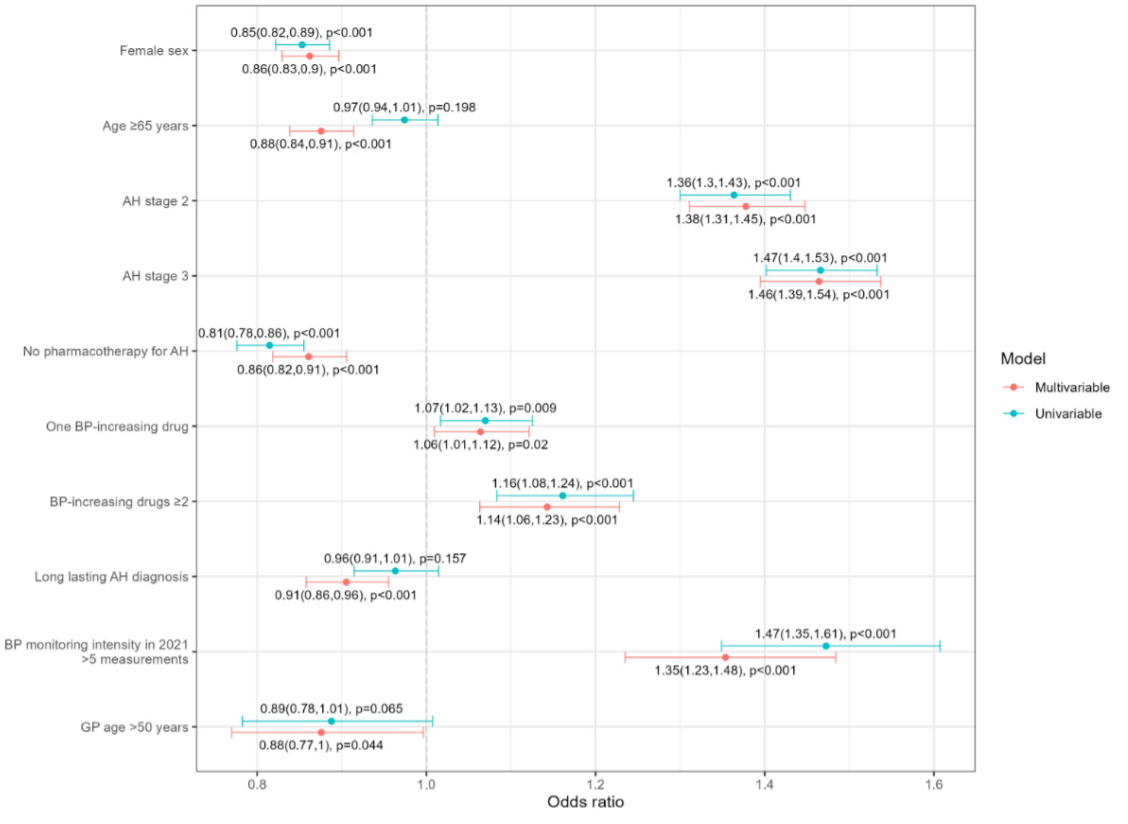
Paradoxically, patients receiving blood pressure-increasing drugs were more likely to have blood pressure control. However, for non-steroidal anti-inflammatory drugs, the most frequently prescribed blood pressure-increasing drugs, the effects on blood pressure control are controversial [29]. In our data, 86% of patients on blood pressure-increasing drugs also received antihypertensive pharmacotherapy, compared with 70% of those not on blood pressure-increasing drugs, potentially offsetting the blood pressure-increasing effects. Moreover, it is possible that general practitioners were aware of the risks and prescribed blood pressure-increasing drugs selectively to patients with relatively low blood pressure levels.

Intensive blood pressure monitoring was also positively associated with blood pressure control, consistent with findings from previous studies that showed the benefits of monitoring interventions on blood pressure control [30–33].

Factors negatively associated with blood pressure control

Other findings warrant attention and could inform future quality improvement efforts. First, patients with long-standing arterial hypertension were less likely to have blood pressure control. This may indicate treatment inertia or status quo bias, which can result in a reluctance to adjust treatment over time [34, 35]. Furthermore, long-standing arterial hypertension leads to vascular remodelling, making it more challenging to treat [36]. Second, we found that female patients were less likely than male patients to have blood pressure control. This could be partly due to the higher proportion of older women in our study, as hypertensive women tend to have stiffer large arteries and consequently higher blood pressure than older men [37]. Although hypertension treatment and blood pressure control are generally less common in men than in women in most countries, this difference is small in high-income countries, and, in line with our findings, a reverse pattern is observed in a few countries [13, 38]. This issue requires further investigation and targeted quality initiatives, especially if unwarranted underuse of guideline-recommended therapy in female patients is contributing to this disparity [39]. Third, older patients were less likely to have blood pressure control. This finding is consistent with previous studies [40] and may be attributed to vascular ageing, degenerative processes [37], or reduced tolerability of antihypertensive pharmacotherapy in older patients. Additionally, general practitioners may be more reluctant to initiate or intensify treatment in older patients. However, the negative association between age and blood pressure control was significant only after adjusting for other potential confounders, suggesting that age alone is not a strong predictor of blood pressure control. Importantly, for patients aged ≥80 years, the risk-benefit ratio of antihypertensive phar-

Figure 3: Unadjusted (univariable) and multivariable (adjusted) logistic mixed regression model (forest plot) of blood pressure control. General practitioners (GPs) were considered as random effects. AH: arterial hypertension; BP: blood pressure; OR: odds ratio; CI: confidence interval.



macotherapy remains unclear, but age alone should not justify treatment de-intensification [9, 10].

Finally, although the negative association between general practitioner age and blood pressure control was statistically significant, its relevance was limited. This is a novel finding that requires further research, though it may be explained by the higher proportion of older patients cared for by older general practitioners in our study.

Pharmacotherapy

Regarding pharmacotherapy, our findings were consistent with those of the SWISSHYPE study [14], which examined general practice patients receiving treatment for arterial hypertension in 2009: approximately one-third of patients received monotherapy, one-quarter received dual therapy, one-fifth were on triple therapy, and one-fifth received a fixed-dose combination. Both low adherence to medication and a "sequential monotherapy" treatment strategy may impede blood pressure control [10]. Most patients in randomised controlled arterial hypertension trials ultimately required combination therapy to control their blood pressure [41], and the PATHWAY study found that initial combination therapy resulted in higher blood pressure control rates than sequential monotherapy [42], likely due to the synergistic effects of different pharmacological mechanisms. Moreover, a recent meta-analysis found that single-pill combination therapy was superior to free-equivalent combination therapy in terms of drug adherence, persistence, and blood pressure control [43]. Increasing the use of fixed-dose combinations is therefore a promising strategy to improve blood pressure control, as recommended by the new ESC guidelines [44]. Nonetheless, in our study, fixed-dose combinations were used in only approximately 30% of treated patients. However, the availability of dual and triple-fixed-dose antihypertensive combinations is steadily increasing, which may increase the proportion of combination therapies.

The prevalence of beta-blocker prescriptions as monotherapy was higher than in the SWISSHYPE study [14]. Since treatment with beta-blockers is recommended for arterial hypertension treatment only under specific conditions [44], our findings suggest a gap between guidelines and practice in the management of arterial hypertension that requires further investigation.

Strengths and limitations

The strengths of this study include its size and representativeness, as it draws on the large FIRE database [45]. Furthermore, we identified patients with arterial hypertension not only through diagnostic codes and pharmacotherapy but also by including blood pressure measurements. This approach provided valuable insights into the management of patients, including those who did not receive pharmacotherapy, and allowed us to study different blood pressure goals. Our approach to identifying patients based on electronic records is highly reproducible and can be utilised in follow-up studies and interventional studies aimed at improving the quality of care at the general practitioner level. A further strength of this study is its novel consideration of both patient and general practitioner characteristics as potential factors associated with blood pressure control.

The main limitation of this study is the potential for misclassification. Firstly, although there are established guidelines for measuring blood pressure [46], we cannot confirm that a standardised measurement protocol was always followed. However, it is highly likely that most blood pressure measurements in the electronic medical records were office-based readings, which can detect "white coat hypertension" in up to 24% of cases [47, 48]. This "white coat hypertension" can be reproduced in about half of patients after a single measurement [49], and since 11% of patients in our sample were identified solely by blood pressure measurement, up to 5% may have been misclassified as having arterial hypertension, potentially biasing the blood pressure control rate towards a lower proportion. Secondly, false-positive identification based on pharmacotherapy cannot be ruled out, especially in cases where antihypertensive drugs were prescribed primarily for other cardiovascular indications, such as heart disease. However, since most cases of heart disease are associated with arterial hypertension (even if not formally diagnosed), this may be of limited concern. Thirdly, we used arterial hypertension staging criteria according to the 2018 ESC/ESH guidelines [10], but without access to information on hypertension-mediated organ damage, which was unavailable in our database. This may have led to an overestimation of the number of stage 1 patients at the expense of stage 2 patients. However, given that cardiovascular disease is likely to be accurately detected in our database, the main results of our study are unlikely to be affected by this limitation.

Fourthly, we acknowledge that about half of the patients with arterial hypertension were excluded because they did not have any blood pressure measurements in 2021. This could affect the validity of our results concerning blood pressure control, as blood pressure control is contingent upon blood pressure measurements being recorded.

Another limitation is the study design, which did not allow for the investigation of causality, only associations with blood pressure control. Moreover, we lacked information on several factors that could have influenced blood pressure control, such as patient awareness of arterial hypertension, lifestyle (diet, physical activity, stress), socio-economic and educational status, non-pharmacological treatment, or compliance with pharmacotherapy [44, 50].

Conclusions

Our findings suggest that general practitioners are adopting a risk-stratified management strategy for patients with arterial hypertension, in line with the revised guidelines. This represents a paradigm shift compared to the management strategies employed a decade ago. However, uncontrolled arterial hypertension remains prevalent in Swiss general practice, and there is significant potential to improve the quality of care, particularly for patients not receiving arterial hypertension pharmacotherapy, those with long-standing arterial hypertension, female sex or old age. The results of this study may inform policymakers and health professionals in designing interventions to enhance blood pressure control.

Open science

An unpublished research protocol was used to guide the study. Data supporting the results are not publicly available due to institutional data protection restrictions but can be obtained from the corresponding author upon reasonable request, along with the R-script used for the statistical analysis.

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Potential competing interests
All authors have completed and submitted the International Committee of Medical Journal Editors form for disclosure of potential conflicts of interest. *RB* has received speaker fees from Servier Pharmaceuticals. The other authors did not disclose individual conflicts of interest related to the content of this manuscript.

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Appendix

Table S1. Comorbidity definitions (co-occurring conditions)*. Each definition, at a particular time, is based on the occurrence of one of the three conditions: ICPC-2 codes, laboratory values or vital signs, medications.

Disease	ICPC-2 codes	Laboratory values or vital signs	Medications
Obesity	T82	one value of BMI ≥ 30	ATC A08AB
Chronic kidney disease Grade 3 Grade 4-5		two measurements with GFR<60. The second one occurring after 90 days from the first one. GFR 30-59 ml/min/1.73m^2 GFR <30 ml/min/1.73m^2	
Dyslipidemia	T93	two of the following: a) triglyceride >1.7 mmol/l; b) total cholesterol > 4.9 mmol/l; c) LDL >3 mmol/l; d) female and HDL ≤1.2 mmol/l; f) male and HDL ≤1 mmol/l	ATC C10
Diabetes mellitus	T89/T90	two consecutive HbA1c ≥ 6.5	ATC A10 excluding (A10BJ)
History of smoking	P17		
Cardiovascular diseases			
Heart disease (heart failure or atrial fibrillation)	K77 K78		ATC C01AA05, C01BC03, C01BC04, C01BD01, C01BD07
Obstructive atherosclerotic disease (coronary, cerebral or peripheral arteries)	K74 K75 K76 K89 K90 K91 K92		ATC B01AC04, B01AC06, B01AC07, B01AC22, B01AC24, B01AC25, B01AC56
Pulmonary heart disease	K82		PCG Pulmonary (arterial) hypertension

* see reference [19] main manuscript.

Abbreviation: GFR, glomerular filtration rate; ATC, anatomical therapeutic chemical classification system; LDL, low density lipoprotein; HDL, high density lipoprotein; HbA1c, hemoglobin A1c; PCG, pharmaceutical cost groups.

Table S2. Antihypertensive medications and blood pressure (BP) increasing medication definitions

Class	Abbreviation	ATC codes
Antihypertensive		
Low ceiling diuretics thiazide type	LCDT	C03A
Low ceiling diuretics other types	LCDO	C03B
Low ceiling diuretics with potassium sparing agents (fixed dose combination)	LCD-P	C03EA
Disregarded diuretics	NA-D	C03C, C03D, C03ED, C03X
Beta blocking agents plain	BB	C07A
BB with diuretics (fixed dose combination)	BB-D	C07B, C07C, C07D
BB with calcium channel blockers (fixed dose combination)	BB-CCB	C07FB
Calcium channel blockers with mainly vascular effects plain	CCB	C08C
CCB with diuretics (fixed dose combination)	CCB-D	C08G
Angiotensin converting enzyme inhibitors, plain	ACEI	C09AA
ACEI with diuretics (fixed dose combination)	ACEI-D	C09BA
ACEI with CCB (fixed dose combination)	ACEI-CCB	C09BB
ACEI with CCB +diuretics (fixed dose combination)	ACEI-CCB-D	C09BX01, C09BX03
ACEI in other combinations –diuretics (fixed dose)	ACEI-O	C09BX02, C09BX04, C09BX05
Angiotensin receptor blockers, plain	ARB	C09CA
ARB with diuretics (fixed dose combination)	ARB-D	C09DA
ARB with CCB (fixed dose combination)	ARB-CCB	C09DB
Angiotensin receptor blockers in combinations with CCB +diuretics	ARB-CCB-D	C09DX01, C09DX03, C09DX06, C09DX07

ARB in other combinations –diuretics (fixed dose)	ARB-O	C09DX02, C09DX04, C09DX05
Other antihypertensive	O	C02AA01, C02AA02, C02AA03, C02AA04, C02AA05, C02AA06, C02AA07, C02AA52, C02AA53, C02AA57, C02AB01, C02AB02, C02AC01, C02AC02, C02AC04, C02AC05, C02AC06, C02AC07, C02AP01, C02AP51, C02BA01, C02BB01, C02CA01, C02CA02, C02CA03, C02CA04, C02CA06, C02CA07, C02CA08, C02CC01, C02CC02, C02CC03, C02CC04, C02CC05, C02CC06, C02CC07, C02DA01, C02DB01, C02DB02, C02DB03, C02DB04, C02DC01, C02DD01, C02DG01, C02KA01, C02KB01, C02KC01, C02KD01, C02KH01, C02KH10, C02KH20, C02KP01, C02KP02, C02KP30, C02KP52, C02KX01, C02KX02, C02KX03, C02KX04, C02KX05, C02KX06, C02KX07, C02KX08, C02KX09, C02KX52, C02LA03, C02LA08, C02LA50, C02LC01, C02LC05, C09XA01, C09XA02, C09XA53
Other antihypertensive in combination with diuretics	O-D	C02LA01, C02LA02, C02LA04, C02LA07, C02LA09, C02LA51, C02LA52, C02LA58, C02LA71, C02LB01, C02LC51, C02LE01, C02LF01, C02LG01, C02LG02, C02LG03, C02LG51, C02LG73, C02LK01, C02LL01, C02LX01, C09XA52, C09XA54
Disregarded others	NA	C07E, C07F, C07X, C08D, C08E
BP - increasing medications		
Antidepressants		N06CA, N06A
NSAIDs (Nonsteroidal anti-inflammatory drugs)		M01A
Steroids		G01BA, G01BD, G01BE, M01BA, H02A, H02B, A14
Oestrogens or testosterone		G02BB, G03AA, G03AB, G03BA, G03HB, G03XC, L02AA, G03C, G03E, G03F
Stimulants		R07AB, C01C, N06B, A15
Anti-obesity agents		A08A
Decongestants		S01GA, R01 (excluding R01AD)
Antipsychotics		N05A

Table S3. Definitions of AH stage adapted for use with FIRE (Family Medicine Research using Electronic Medical Records) data.

Variable	Comorbidity / risk factor
AH stage	
Stage 1	≤3 cardiovascular risks (dyslipidemia, obesity, history of smoking, chronic kidney disease grade <3)
Stage 2	Diabetes mellitus or chronic kidney disease grade 3
Stage 3	Chronic kidney disease grade 4-5 or established cardiovascular disease

Table S4. Antihypertensive pharmacotherapy (ATC codes) overall and stratified by patients with and without blood pressure control (BPC).

		Overall	Patients without BPC	Patients with BPC
	n ATC	69,704	36,599	33,105
	n patients	36,692	19,209	17,483
ATC	Drug name			
C02AB01	Methyldopa (Levorotatory)	12 (0.0)	7 (0.0)	5 (0.0)
C02AC01	Clonidine	29 (0.0)	18 (0.0)	11 (0.0)
C02AC05	Moxonidine	273 (0.4)	157 (0.4)	116 (0.4)
C02CA04	Tolonidine	215 (0.3)	139 (0.4)	76 (0.2)
C02DC01	Minoxidil	29 (0.0)	15 (0.0)	14 (0.0)
C02KX01	Bosentan	7 (0.0)	1 (0.0)	6 (0.0)
C02KX02	Ambrisentan	1 (0.0)	1 (0.0)	0 (0.0)
C02KX04	Macitentan	14 (0.0)	5 (0.0)	9 (0.0)
C02KX05	Riociguat	8 (0.0)	5 (0.0)	3 (0.0)
C02LA51	Reserpine and Diuretics	1 (0.0)	1 (0.0)	0 (0.0)
C03AA03	Hydrochlorothiazide	435 (0.6)	222 (0.6)	213 (0.6)
C03BA04	Chlortalidone	21 (0.0)	11 (0.0)	10 (0.0)
C03BA08	Metolazone	228 (0.3)	64 (0.2)	164 (0.5)
C03BA11	Indapamide	762 (1.1)	437 (1.2)	325 (1.0)
C03EA01	Hydrochlorothiazide and Potassium-Sparing Agents	547 (0.8)	293 (0.8)	254 (0.8)
C07AA03	Pindolol	1 (0.0)	0 (0.0)	1 (0.0)
C07AA05	Propranolol	1076 (1.5)	470 (1.3)	606 (1.8)
C07AA07	Sotalol	119 (0.2)	58 (0.2)	61 (0.2)
C07AB02	Metoprolol	5219 (7.5)	2433 (6.6)	2786 (8.4)

C07AB03	Atenolol	669 (1.0)	357 (1.0)	312 (0.9)
C07AB07	Bisoprolol	6053 (8.7)	2855 (7.8)	3198 (9.7)
C07AB08	Celiprolol	12 (0.0)	6 (0.0)	6 (0.0)
C07AB12	Nebivolol	2428 (3.5)	1222 (3.3)	1206 (3.6)
C07AG01	Labetalol	19 (0.0)	11 (0.0)	8 (0.0)
C07AG02	Carvedilol	547 (0.8)	270 (0.7)	277 (0.8)
C07BB07	Bisoprolol and Thiazides	459 (0.7)	240 (0.7)	219 (0.7)
C07BB12	Nebivolol and Thiazides	42 (0.1)	24 (0.1)	18 (0.1)
C07CA03	Pindolol and other diuretics	4 (0.0)	2 (0.0)	2 (0.0)
C07CB02	Metoprolol and other diuretics	8 (0.0)	5 (0.0)	3 (0.0)
C07CB03	Atenolol and other diuretics	252 (0.4)	131 (0.4)	121 (0.4)
C07FB02	Metoprolol and Felodipine	149 (0.2)	84 (0.2)	65 (0.2)
C07FB03	Atenolol and Nifedipine	9 (0.0)	3 (0.0)	6 (0.0)
C08CA01	Amlodipine	8054 (11.6)	4477 (12.2)	3577 (10.8)
C08CA02	Felodipine	272 (0.4)	142 (0.4)	130 (0.4)
C08CA03	Isradipine	10 (0.0)	8 (0.0)	2 (0.0)
C08CA05	Nifedipine	950 (1.4)	539 (1.5)	411 (1.2)
C08CA06	Nimodipine	3 (0.0)	0 (0.0)	3 (0.0)
C08CA08	Nitrendipine	2 (0.0)	0 (0.0)	2 (0.0)
C08CA13	Lercanidipine	1892 (2.7)	1128 (3.1)	764 (2.3)
C09AA01	Captopril	13 (0.0)	5 (0.0)	8 (0.0)
C09AA02	Enalapril	738 (1.1)	370 (1.0)	368 (1.1)
C09AA03	Lisinopril	5926 (8.5)	3071 (8.4)	2855 (8.6)
C09AA04	Perindopril	2446 (3.5)	1305 (3.6)	1141 (3.4)
C09AA05	Ramipril	1913 (2.7)	889 (2.4)	1024 (3.1)

C09AA06	Quinapril	21 (0.0)	10 (0.0)	11 (0.0)
C09AA07	Benazepril	6 (0.0)	2 (0.0)	4 (0.0)
C09AA08	Cilazapril	23 (0.0)	12 (0.0)	11 (0.0)
C09BA01	Captopril and Diuretics	29 (0.0)	10 (0.0)	19 (0.1)
C09BA02	Enalapril and Diuretics	428 (0.6)	223 (0.6)	205 (0.6)
C09BA03	Lisinopril and Diuretics	2135 (3.1)	1182 (3.2)	953 (2.9)
C09BA04	Perindopril and Diuretics	1262 (1.8)	679 (1.9)	583 (1.8)
C09BA05	Ramipril and Diuretics	235 (0.3)	127 (0.3)	108 (0.3)
C09BA06	Quinapril and Diuretics	16 (0.0)	11 (0.0)	5 (0.0)
C09BA07	Benazepril and Diuretics	5 (0.0)	3 (0.0)	2 (0.0)
C09BA08	Cilazapril and Diuretics	20 (0.0)	12 (0.0)	8 (0.0)
C09BA09	Fosinopril and Diuretics	7 (0.0)	5 (0.0)	2 (0.0)
C09BB02	Enalapril and Lercanidipine	42 (0.1)	26 (0.1)	16 (0.0)
C09BB04	Perindopril and Amlodipine	1492 (2.1)	760 (2.1)	732 (2.2)
C09BB10	Trandolapril and Verapamil	22 (0.0)	11 (0.0)	11 (0.0)
C09BX01	Perindopril, Amlodipine and Indapamide	690 (1.0)	342 (0.9)	348 (1.1)
C09BX02	Perindopril and Bisoprolol	65 (0.1)	28 (0.1)	37 (0.1)
C09CA01	Losartan	1244 (1.8)	672 (1.8)	572 (1.7)
C09CA02	Eprosartan	21 (0.0)	9 (0.0)	12 (0.0)
C09CA03	Valsartan	2671 (3.8)	1527 (4.2)	1144 (3.5)
C09CA04	Irbesartan	1028 (1.5)	570 (1.6)	458 (1.4)
C09CA06	Candesartan	4630 (6.6)	2526 (6.9)	2104 (6.4)
C09CA07	Telmisartan	360 (0.5)	192 (0.5)	168 (0.5)

C09CA08	Olmesartan Medoxomil	556 (0.8)	287 (0.8)	269 (0.8)
C09CA09	Azilsartan Medoxomil	83 (0.1)	44 (0.1)	39 (0.1)
C09DA01	Losartan and Diuretics	663 (1.0)	358 (1.0)	305 (0.9)
C09DA02	Eprosartan and Diuretics	15 (0.0)	7 (0.0)	8 (0.0)
C09DA03	Valsartan and Diuretics	1528 (2.2)	864 (2.4)	664 (2.0)
C09DA04	Irbesartan and Diuretics	968 (1.4)	571 (1.6)	397 (1.2)
C09DA06	Candesartan and Diuretics	2159 (3.1)	1166 (3.2)	993 (3.0)
C09DA07	Telmisartan and Diuretics	183 (0.3)	102 (0.3)	81 (0.2)
C09DA08	Olmesartan Medoxomil and Diuretics	287 (0.4)	142 (0.4)	145 (0.4)
C09DA09	Azilsartan Medoxomil and Diuretics	168 (0.2)	87 (0.2)	81 (0.2)
C09DB01	Valsartan and Amlodipine	1667 (2.4)	939 (2.6)	728 (2.2)
C09DB02	Olmesartan Medoxomil and Amlodipine	666 (1.0)	374 (1.0)	292 (0.9)
C09DB04	Telmisartan and Amlodipine	68 (0.1)	34 (0.1)	34 (0.1)
C09DB07	Candesartan and Amlodipine	14 (0.0)	11 (0.0)	3 (0.0)
C09DX01	Valsartan, Amlodipine and Hydrochlorothiazide	1502 (2.2)	827 (2.3)	675 (2.0)
C09DX03	Olmesartan Medoxomil, Amlodipine and Hydrochlorothiazide	308 (0.4)	170 (0.5)	138 (0.4)
C09DX04	Valsartan and Sacubitril	335 (0.5)	66 (0.2)	269 (0.8)
C09XA02	Valsartan and Nebivol	127 (0.2)	79 (0.2)	48 (0.1)

C09XA52	Aliskiren and Hydrochlorothiazide	88 (0.1)	51 (0.1)	37 (0.1)

Table S5. Logistic mixed regression model details (adjusted/unadjusted) justifying the final model of blood pressure control (BPC) in Figure 3 (main manuscript). General practitioners were considered as random effects. OR, odds ratio; CI, confidence interval.

		Patients without BPC n (%)	**Patients with BPC n (%)**	**OR univariable (unadjusted) OR (95% CI), p-value**	**OR multivariable (adjusted) OR (95% CI), p-value**	**Final model (adjusted) OR (95% CI), p-value**
Sex	male	13,069 (49.8)	12,286 (53.4)	-	-	-
	female	13,198 (50.2)	10,735 (46.6)	0.85 (0.82-0.89), p<0.001	0.86 (0.83-0.90), p<0.001	0.86 (0.83-0.90), p<0.001
Age (years)	<65	8704 (33.1)	7731 (33.6)	-	-	-
	≥65	17,564 (66.9)	15,291 (66.4)	0.97 (0.94-1.01), p=0.198	0.87 (0.83-0.91), p<0.001	0.88 (0.84-0.91), p<0.001
AH stage	stage 1	13,923 (53.0)	10,379 (45.1)	-	-	-
	stage 2	5458 (20.8)	5439 (23.6)	1.36 (1.30-1.43), p<0.001	1.38 (1.31-1.45), p<0.001	1.38 (1.31-1.45), p<0.001
	stage 3	6887 (26.2)	7204 (31.3)	1.47 (1.40-1.53), p<0.001	1.47 (1.40-1.55), p<0.001	1.46 (1.39-1.54), p<0.001
AH pharmacotherapy	yes	19,209 (73.1)	17,483 (75.9)	-	-	-
	no	7059 (26.9)	5539 (24.1)	0.81 (0.78-0.86), p<0.001	0.87 (0.82-0.91), p<0.001	0.86 (0.82-0.91), p<0.001
	0	18,396 (70.0)	16,298 (70.8)	-	-	-

Number of BP-increasing drugs	1	5403 (20.6)	4567 (19.8)	1.07 (1.02-1.13), p=0.009	1.06 (1.00-1.12), p=0.045	1.06 (1.01-1.12), p=0.020
	≥2	2469 (9.4)	2157 (9.4)	1.16 (1.08-1.24), p<0.001	1.13 (1.05-1.21), p=0.002	1.14 (1.06-1.23), p<0.001
Long-lasting AH diagnosis (≥ 5 years)	no	19,064 (72.6)	16,573 (72.0)	-	-	-
	yes	7204 (27.4)	6449 (28.0)	0.96 (0.91-1.01), p=0.157	0.91 (0.86-0.96), p=0.001	0.91 (0.86-0.96), p<0.001
Intensity of BP monitoring in 2021 (number of measurements)	≤5	25,156 (95.8)	21,753 (94.5)	-	-	-
	>5	1112 (4.2)	1269 (5.5)	1.47 (1.35-1.61), p<0.001	1.37 (1.25-1.50), p<0.001	1.35 (1.23-1.48), p<0.001
GP workload (% of full-time equivalent)	≤50%	3292 (13.1)	2782 (12.6)	-	-	
	51-80%	9993 (39.9)	9216 (41.6)	1.12 (0.95-1.31), p=0.181	1.10 (0.90-1.33), p=0.355	
	> 80%	11,762 (47.0)	10,135 (45.8)	0.97 (0.81-1.15), p=0.683	0.93 (0.74-1.17), p=0.545	
GP working position	employee	8417 (34.9)	7255 (34.1)	-	-	
	self-employed	15,715 (65.1)	14,031 (65.9)	1.05 (0.92-1.19), p=0.509	1.10 (0.95-1.28), p=0.219	
GP age (years)	≤50	8851 (35.4)	8172 (37.0)	-	-	-
	>50	16,135 (64.6)	13,927 (63.0)	0.89 (0.78-101), p=0.065	0.82 (0.71-0.95), p=0.008	0.88 (0.77-1.00), p=0.044

GP sex	female	7809 (29.7)	6644 (28.9)	-	-	
	male	18,459 (70.3)	16,378 (71.1)	1.03 (0.91-1.17), p=0.606	1.04 (0.88-1.22), p=0.676	
Practice location area*	urban	9877 (37.6)	8782 (38.1)	-	-	
	suburban	14,309 (54.5)	11,823 (51.4)	0.88 (0.78-1.00), p=0.056	0.87 (0.75-1.01), p=0.060	
	rural	2082 (7.9)	2417 (10.5)	1.19 (0.96-1.48), p=0.112	1.12 (0.88-1.41), p=0.350	
Practice Organization Form	double	1685 (6.4)	1415 (6.1)	-	-	
	single	3580 (13.6)	3072 (13.3)	0.94 (0.68-1.30), p=0.705	1.06 (0.75-1.50), p=0.748	
	group	21,003 (80.0)	18,535 (80.5)	0.92 (0.71-1.20), p=0.546	0.99 (0.75-1.30), p=0.925	

* Eurostat Degree of Urbanization index in Switzerland, see reference [23] main manuscript.

Abbreviation: AH, arterial hypertension; BP, blood pressure; GP, general practitioner.

Table S6. Numbers of BP-increasing drugs overall and stratified by blood pressure control (BPC).

	Overall	Patients without BPC	Patients with BPC
n	49,290	26,268	23,022
N of BP-increasing drugs n (%)			
0	34,694 (70.4)	18,396 (70.0)	16,298 (70.8)
1	9970 (20.2)	5403 (20.6)	4567 (19.8)
2	3560 (7.2)	1917 (7.3)	1643 (7.1)
≥3	1066 (2.2)	552 (2.1)	514 (2.2)
Median (IQR)	0 (0-1)	0 (0-1)	0 (0-1)
Type of drug n (%)			
Antidepressants	5362 (10.9)	2740 (10.4)	2622 (11.4)
NSAIDS	8807 (17.9)	4939 (18.8)	3868 (16.8)
Steroids	1971 (4.0)	1061 (4.0)	910 (4.0)
Estrogens/testorene	1330 (2.7)	792 (3.0)	538 (2.3)
Stimulants	316 (0.6)	171 (0.7)	145 (0.6)
Anti-obesity	54 (0.1)	28 (0.1)	26 (0.1)
Decongestants	1285 (2.6)	682 (2.6)	603 (2.6)
Anti-psychotics	1381 (2.8)	591 (2.2)	790 (3.4)

Abbreviation: NSAIDS, nonsteroidal anti-inflammatory drugs; BP, blood pressure; IQR, interquartile range.

Figure S1. Inclusion criteria. Flow chart. BP, blood pressure; SBP, systolic BP; DBP, diastolic BP.

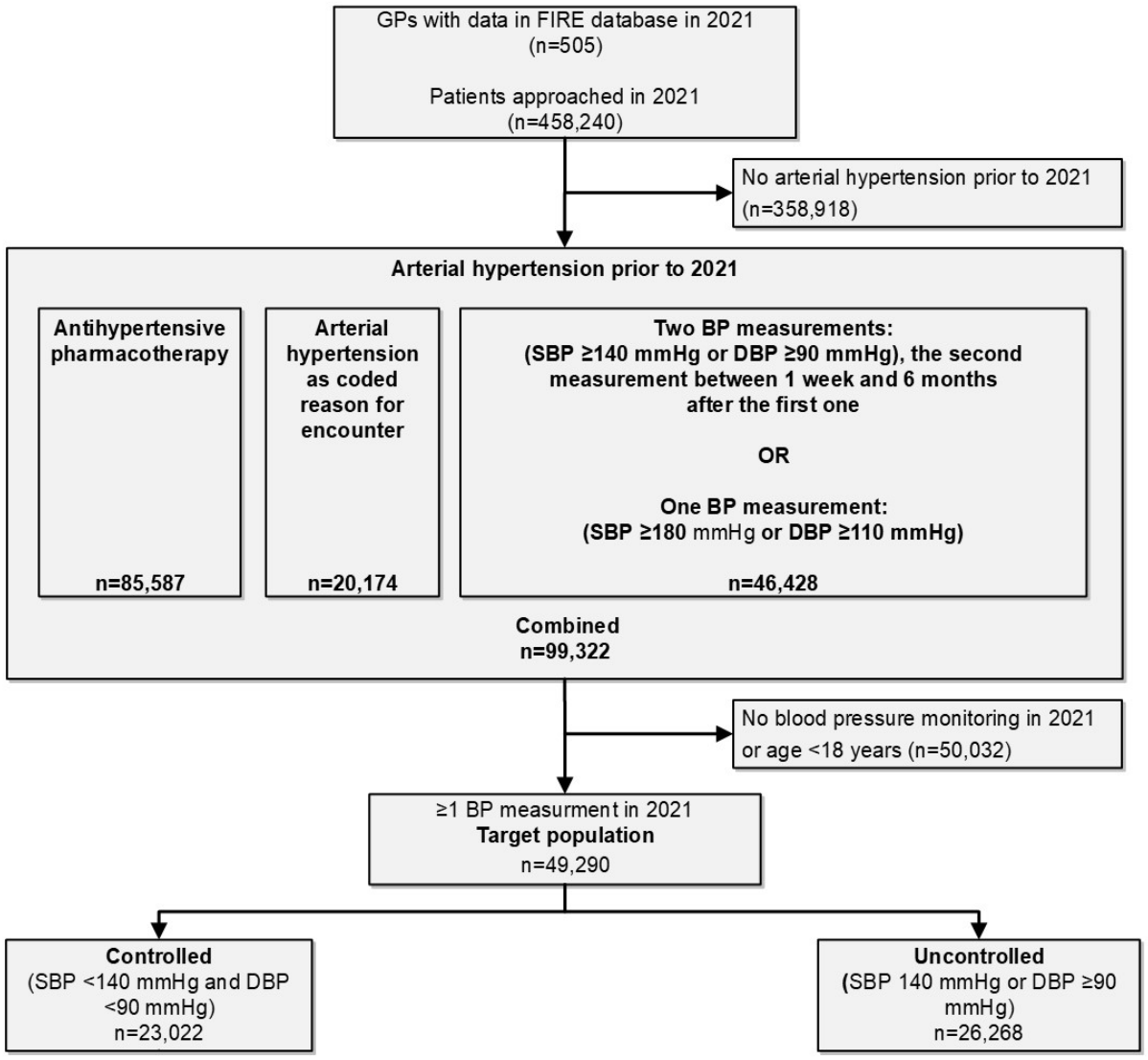


Figure S2. Arterial hypertension (AH) patient identification criteria. Venn diagram showing the number (% percentage) of patients with one or more of the three conditions: medication (antihypertensive pharmacotherapy); vital (blood pressure (BP) measurements as described in Figure S1); ICPC-2 (AH as reason for encounter) for arterial hypertension before 2021 and also meeting the other inclusion criteria on age and BP monitoring in 2021.

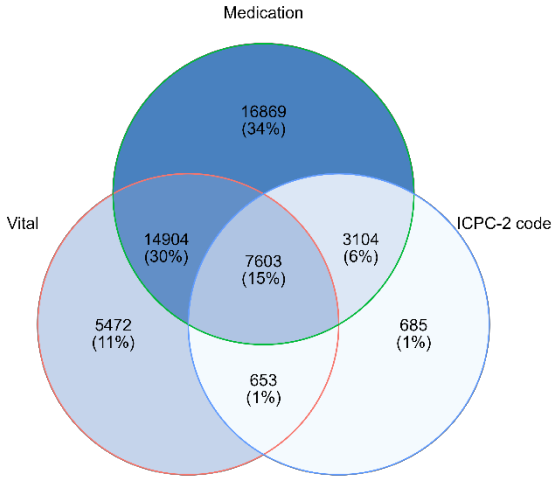


Figure S3. Blood pressure (BP) distribution. Dashed line represent the primary BP goal threshold.

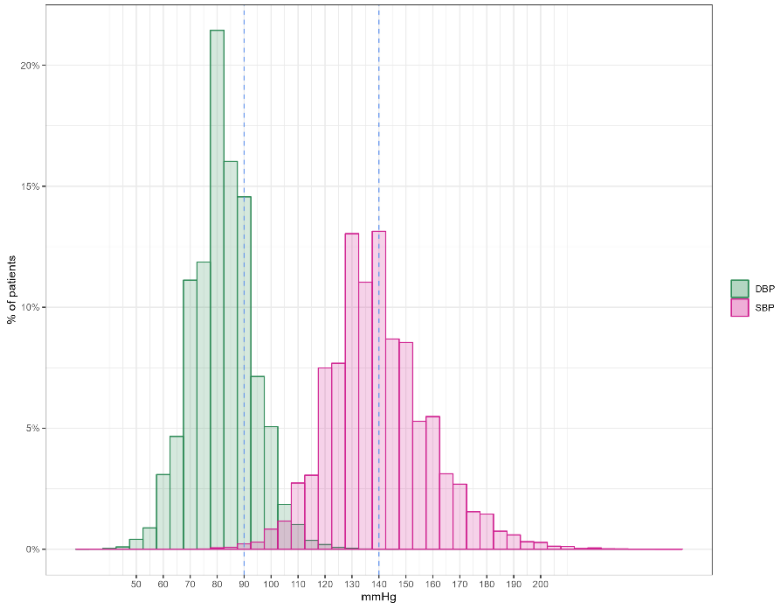
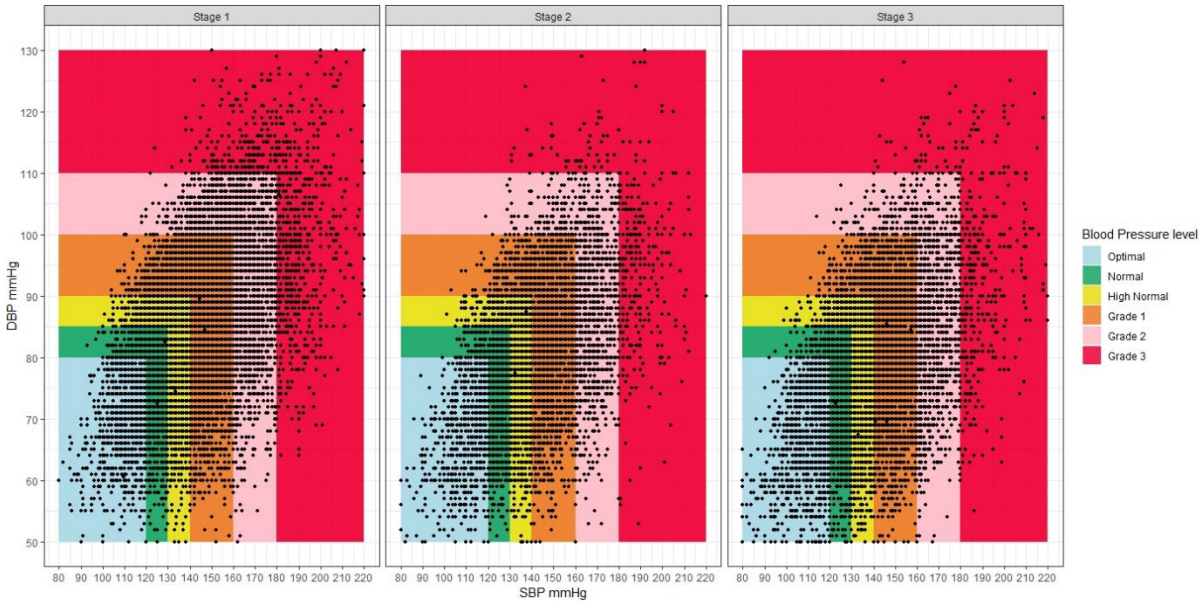


Figure S4. Blood Pressure Chart and scatterplot stratified by arterial hypertension (AH) stage. Blood pressure levels are defined according to the 2018 ESC/ESH guidelines for the management of arterial hypertension (see reference [10] main manuscript). Number and percentages for each level are also reported.



BP Level n(%)		Overall	Stage 1 AH	Stage 2 AH	Stage 3 AH
Optimal	(SBP <120 mmHg and DBP <80 mmHg)	4081 (8.3)	1486 (6.1)	1038 (9.5)	1557 (11.0)
Normal	(SBP 120–129 mmHg and DBP <85 mmHg) or (SBP <130 mmHg and DBP 80-84 mmHg)	7171 (14.5)	3258 (13.4)	1702 (15.6)	2211 (15.7)
High Normal	(SBP 130–139 mmHg and DBP <90 mmHg) or (SBP <140 mmHg and DBP 85-89 mmHg)	11,770 (23.9)	5635 (23.2)	2699 (24.8)	3436 (24.4)
Grade 1	(SBP 140–159 mmHg and DBP <100 mmHg) or (SBP <160 mmHg and DBP 90–99 mmHg)	17,628 (35.8)	9160 (37.7)	3739 (34.3)	4729 (33.6)
Grade 2	(SBP 160–179 mmHg and DBP <110 mmHg) or (SBP <180 mmHg and DBP 100–109 mmHg)	6658 (13.5)	3687 (15.2)	1312 (12.0)	1659 (11.8)
Grade 3	(SBP ≥180 mmHg or DBP ≥110 mmHg)	1982 (4.0)	1076 (4.4)	408 (3.7)	499 (3.5)

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