

Research Article



Evaluation of guideline adherence to hypertension-mediated organ damage screening in Korean patients with hypertension: results from the Korean Registry of Target Organ Damage in Hypertension (KorHR)

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OPEN ACCESS

Received: Sep 15, 2025

Revised: Nov 19, 2025

Accepted: Feb 2, 2026

Published online: Mar 1, 2026

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ABSTRACT

Background: Adherence to guidelines for hypertension-mediated organ damage (HMOD) assessment has not been extensively studied. We aimed to evaluate guideline adherence to HMOD assessment and to identify factors associated with this adherence.

Methods: In this prospective, multicenter observational study conducted from May 2013 to December 2022, we evaluated adherence to guideline-recommended HMOD screening among 2,070 hypertensive patients enrolled from 24 tertiary care centers in Korea. Patients were categorized as either newly treated or on treatment. The basic screening tests included urine albumin-to-creatinine ratio (UACR), electrocardiography (ECG), and glomerular filtration rate (GFR). The extended screening tests included echocardiography, carotid ultrasonography, fundoscopic examination, ankle-brachial index measurement, and brachial-ankle pulse wave velocity assessment.

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Abbreviations

ABI, ankle-brachial index; baPWV, brachial-ankle pulse wave velocity; CI, confidence interval; DM, diabetes mellitus; ECG, electrocardiography; eGFR, estimated glomerular filtration rate; GFR, glomerular filtration rate; HMOD, hypertension-mediated organ damage; HTN, hypertension; IRB, Institutional Review Board; KSH, Korean Society of Hypertension; LVH, left ventricular hypertrophy; OR, odds ratio; PWV, pulse wave velocity; SBP, systolic blood pressure; TTE, transthoracic echocardiography; UACR, urine albumin-to-creatinine ratio.

Trial Registration

ClinicalTrials.gov Identifier: NCT01861080

Funding

This research was supported by the Korean Society of Hypertension (KSH-R-2022-01). The funders had no roles in the study design, data collection and analysis, decision to publish, or preparation of the article.

Competing interest

The authors declare that they have no competing interests.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The study protocol was approved by the Institutional Review Board of Hallym University Dongtan Sacred Heart Hospital (IRB No. 2012-12-005) and by the IRBs of all other participating centers (**Supplementary Table 1**). The study adhered to the principles of the Declaration

Results: The overall adherence rate for basic screening was 68.4%. Compliance with GFR and ECG assessments was high (90.3% and 95.2%, respectively), whereas adherence to UACR testing was lower (72.5%). The adherence rate for basic screening was significantly lower in the on-treatment group compared with the newly treated group (57.1% vs. 79.9%). Elderly patients (≥ 60 years) exhibited the lowest adherence to basic screening. Further analyses revealed that increasing age was significantly associated with a lower likelihood of completing both basic and extended screenings.

Conclusions: Guideline-recommended HMOD screening remains underutilized in routine clinical practice, particularly among elderly patients. These findings underscore the need to improve adherence to HMOD screening.

Trial Registration: ClinicalTrials.gov Identifier: NCT01861080

Keywords: Hypertension; Guideline adherence; Hypertension-mediated organ damage; Screening

BACKGROUND

Hypertension (HTN) is a major contributor to cardiovascular morbidity and mortality worldwide, and more than half of hypertensive patients have additional cardiovascular risk factors, such as dyslipidemia and glucose intolerance [1]. Given that the combination of metabolic risk factors has a synergistic effect on cardiovascular risk, assessing overall cardiovascular risk is the cornerstone of HTN treatment [2]. Accordingly, contemporary HTN guidelines have incorporated the assessment of hypertension-mediated organ damage (HMOD) into cardiovascular risk evaluation [3-5].

Although target organ damage screening provides clinical benefits, there is concern that physicians do not consistently perform these screenings as recommended by the guidelines [6]. The discrepancy between guideline recommendations and clinical practice may compromise the appropriate management of HTN. However, limited data is available regarding compliance with guidelines for HMOD screening in real-world settings. Therefore, this study aims to evaluate the implementation of HMOD screening and identify factors that impede HMOD screening practice in real-world outpatient clinical settings.

METHODS

Study design

The Korean Registry of Target Organ Damage in Hypertension (KorHR) is a prospective, non-interventional, observational, multicenter cohort study involving 24 tertiary hospitals. The rationale, design, protocol, and interim results for KorHR are published previously [7]. The study was approved by Institutional Review Boards (IRBs) of Hallym University Dongtan Sacred Heart Hospital (IRB No. 2012-12-005) and by the IRBs of all participating sites (**Supplementary Table 1**) and registered at <http://www.clinicaltrials.gov> (trial number: NCT01861080). A total of 2,070 participants were enrolled from May 2013 to December 2022 and all the subjects in the cohort were Asian. Patients were consecutively enrolled if they were older than 30 years and met the inclusion criteria. The inclusion criteria were as follows: patients who either 1) initiated antihypertensive therapy at the time of enrollment, or 2) had already started antihypertensive treatment within the preceding 5 years and had been managed

of Helsinki. Written informed consent was obtained from all enrolled patients.

Consent for publication

Not applicable

Authors' contributions

Conceptualization: Kim DY, Kim SH, Shin MS, Ryu KH; Data curation: Ok JS; Formal analysis: Kim DY, Kim SH, Ryu SK; Investigation: Ok JS, Ryu KH; Methodology: Kim DY, Kim SH; Supervision: Shin MS, Ryu KH; Project administration: Han SW, Son JW, Jeong JO, Kim EJ, Choi S, Jung IH, Ryu SK; Writing - original draft: Kim DY, Kim SH; Writing - review & editing: Kim DY, Kim SH, Han SW, Ok JS, Son JW, Jeong JO, Kim EJ, Choi S, Jung IH, Ryu SK, Shin MS, Ryu KH.

at the study site. All participants provided informed consent to participate in the study. Patients with prior history of cerebrovascular disease, angina, myocardial infarction, heart failure, peripheral artery disease, and stage 4 or 5 chronic kidney disease (estimated glomerular filtration rate [eGFR] of less than 30 mL/min/1.73 m²) were excluded. At the baseline visit, demographic and anthropometric characteristics of the eligible patients were documented. Additionally, medical histories were recorded, including diagnoses of diabetes mellitus (DM), hyperlipidemia, and smoking habits. DM was defined as a fasting plasma glucose level of ≥ 126 mg/dL, hemoglobin A1c level of $\geq 6.5\%$, or the administration of anti-diabetic medications. Hyperlipidemia was characterized by a total cholesterol level of ≥ 240 mg/dL, low-density lipoprotein level of ≥ 160 mg/dL, triglyceride level of ≥ 200 mg/dL, or the use of statin therapy.

Systolic blood pressure (SBP) and diastolic blood pressure were measured 2 or 3 times in both arms at 3-minute intervals, in accordance with official recommendations, using validated oscillometric devices or calibrated aneroid sphygmomanometers [8]. The mean values of each measurement were recorded as the office blood pressures. Additional tests for HMOD, such as 12-lead electrocardiography (ECG), urine albumin-to-creatinine ratio (UACR), transthoracic echocardiography (TTE), carotid artery ultrasound, fundoscopic examination, ankle-brachial index (ABI), and brachial-ankle pulse wave velocity (baPWV), were also conducted at the direction of the physician's instructions. The data were collected using a web-based standardized questionnaire. An audit involving on-site verification of source data was conducted.

For analysis, patients were categorized into 2 groups: the newly treated group and the on-treatment group. The newly treated group included patients who initiated antihypertensive medication at enrollment or had been receiving treatment for less than 1 year. The on-treatment group included patients who had been on continuous antihypertensive therapy for more than 1 year before enrollment.

For data-sharing, de-identified individual-level data will be made available upon reasonable request to the corresponding author. Data sharing will require submission of a data access proposal, approval by the IRB, and execution of a data use agreement. The dataset will be available for academic and non-commercial research purposes only.

Assessment of guideline adherence to HMOD screenings

The 2018 Korean Society of Hypertension (KSH) and the 2023 European Society of Hypertension guidelines recommend assessing HMOD at the time of HTN diagnosis and repeating basic screening tests at least once annually during follow-up [3,4,9]. The UACR, 12-lead ECG, and serum creatinine are recommended as basic screening tests. Additionally, TTE, pulse wave velocity (PWV) measurement, carotid artery ultrasound, ABI, and fundoscopic examinations are recommended as extended screening tests for HMOD screening. To assess adherence to these guidelines, we evaluated adherence rates for basic screening tests and the number of extended screening tests performed at the initiation of antihypertensive medication in the newly treated group. For the on-treatment group, we collected basic HMOD screening data from tests conducted within the previous year at enrollment.

Definition of HMOD category, cardiovascular risk factors, and indication of strict blood pressure control

The categories of HMOD in this study were defined based on the 2018 KSH guideline for the management of HTN [3,9,10]. Renal HMOD includes cases with albuminuria detected

in spot urine or an eGFR below 60 mL/min/1.73 m². Vascular HMOD is defined by an ABI below 0.9, a baPWV of 1,800 cm/s or higher, or the presence of carotid plaques as detected by carotid ultrasonography. Left ventricular hypertrophy (LVH) includes cases diagnosed as LVH based on ECG criteria or confirmed by echocardiography. Retinopathy is classified as HMOD when stages 3–4 hypertensive retinopathy are diagnosed through ophthalmologic examination. The cardiovascular risk factors were defined according to the 2018 KSH guideline, as follows [3]: men aged ≥ 45 years or women aged ≥ 55 years, family history of premature cardiovascular disease (early onset cardiovascular disease in a first-degree relative, defined as onset in men younger than 55 years or in women younger than 65 years), current smoking, obesity (body mass index ≥ 25 kg/m²), abdominal obesity (waist circumference thresholds of ≥ 90 cm in men and ≥ 85 cm in women.), dyslipidemia (total cholesterol ≥ 220 mg/dL, low density lipoprotein cholesterol ≥ 150 mg/dL, high-density lipoprotein cholesterol < 40 mg/dL, triglycerides ≥ 200 mg/dL), and prediabetes or impaired glucose tolerance (fasting plasma glucose ≥ 100 mg/dL but < 126 mg/dL or DM). Strict blood pressure control ($< 130/80$ mmHg) was defined according to the 2018 KSH guideline [3]. Patients requiring strict control included those with 3 or more cardiovascular risk factors, diabetes plus at least one cardiovascular risk factor, or any HMOD.

Statistical analysis

Continuous variables are expressed as means and standard deviations, and categorical data are expressed as numbers and percentages. For comparisons across groups, continuous variables were compared using Student's *t*-test and categorical variables were analyzed using the χ^2 test or Fisher's exact test, as appropriate. In addition, multiple logistic regression analyses were performed to identify independent predictors of basic screening adherence, with results presented as odds ratios (ORs) and 95% confidence intervals (CIs). Furthermore, multiple linear regression models were used to evaluate the associations between predictor variables and number of extended screenings, adjusting for potential confounders. Statistical analyses were performed using R software (version 3.2.1; R Foundation for Statistical Computing, Vienna, Austria). With regard to the handling of missing data, no imputation was performed because the proportion of missing values for each variable was below 5%.

RESULTS

Baseline demographics

Baseline characteristics of the study population are presented in **Table 1**. The mean age of the overall population was 52.2 ± 12.0 years. Men accounted for 61.6% of the cohort, and the overall prevalence of DM was 10.9%. The newly treated group had a mean HTN duration of 15.9 months, while the on-treatment group had a mean duration of 90.6 months. Among antihypertensive agents, calcium channel blockers were the most frequently used antihypertensive agent (59.0%), and 35.0% of participants were on fixed-drug combination therapy.

Prevalence of HMODs

Fig. 1 shows the prevalence of HMOD in the on-treatment and newly treated groups, as well as in the overall study population. The detection rate of any HMOD was significantly higher in the newly treated group than in the on-treatment group (40.0% vs. 32.8%, $P < 0.001$). The prevalence of retinopathy was 0.8% in the newly treated group, whereas no cases were detected in the on-treatment group. Vascular HMOD was observed in 13.2% of the on-treatment group and 14.3% of the newly treated group. Renal HMOD (18.2% vs. 11.8%,

Table 1. Baseline characteristics

	Newly treated (n = 1,326)	On-treatment (n = 744)	Total (n = 2,070)
Age (yr)	49.2 ± 11.4	57.4 ± 11.2	52.2 ± 12.0
Male	839 (63.3)	436 (58.6)	1,275 (61.6)
SBP (mmHg)	147.3 ± 19.8	130.8 ± 14.0	141.3 ± 19.6
DBP (mmHg)	91.9 ± 14.7	78.2 ± 11.0	87.0 ± 15.0
HR (bpm)	76.3 ± 12.5	72.2 ± 11.4	74.8 ± 12.3
HTN duration (mon)	15.9 ± 33.3	90.6 ± 78.0	42.7 ± 64.7
Family history of early CVD	610 (46.0)	306 (41.1)	916 (44.3)
Current smoker	226 (17.1)	111 (14.9)	337 (16.3)
DM	126 (9.5)	99 (13.3)	225 (10.9)
Dyslipidemia	489 (36.9)	405 (54.4)	894 (43.2)
BMI (kg/m ²)	26.2 ± 3.7	25.8 ± 3.4	26.1 ± 3.6
Waist (cm)	89.1 ± 9.3	87.8 ± 9.2	88.6 ± 9.3
LDL (mg/dL)	124.2 ± 36.2	104.2 ± 30.9	116.1 ± 35.7
Glucose (mg/dL)	97.9 ± 38.6	99.0 ± 40.9	98.3 ± 39.5
eGFR	90.4 ± 21.4	85.5 ± 18.6	88.6 ± 20.6
ACEI	50 (3.8)	14 (2.0)	64 (3.2)
ARB	688 (51.9)	459 (61.7)	1,147 (55.4)
Diuretics	82 (6.2)	79 (10.6)	161 (7.8)
CCB	800 (60.4)	420 (56.5)	1,220 (59.0)
Beta blocker	95 (7.2)	141 (19.0)	236 (11.4)
Fixed drug combination	422 (31.8)	302 (40.6)	724 (35.0)

Values are shown as mean ± standard deviation for continuous variables and number (percentage) for categorical variables.

SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; HTN, hypertension; CVD, cardiovascular disease; DM, diabetes mellitus; BMI, body mass index; LDL, low density lipoprotein; eGFR, estimated glomerular filtration rate; ACEI, angiotensin converting enzyme inhibitor; ARB, angiotensin receptor blocker; CCB, calcium channel blocker.

$P < 0.001$) and LVH (19.1% vs. 14.7%, $P < 0.001$) were significantly more prevalent in the newly treated group than in the on-treatment group. Overall, the prevalence of LVH and renal HMOD was 17.5% and 15.9%, respectively.

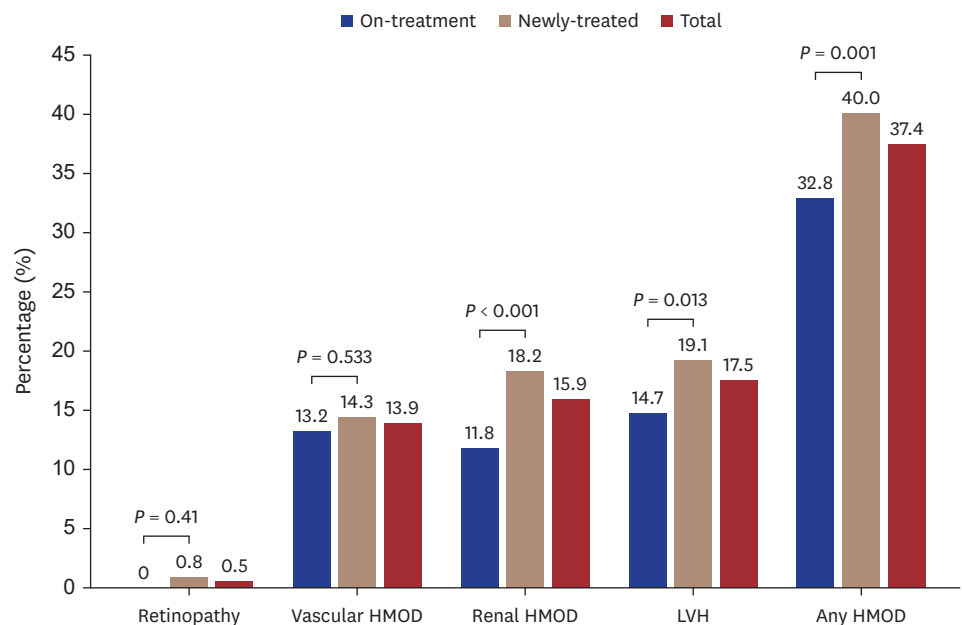


Fig. 1. Prevalence of HMOD subtypes in on-treatment and newly treated patients, and in the overall study population. The prevalence of each HMOD subtype was calculated based on the entire cohort, including individuals who did not undergo the corresponding HMOD screening test. HMOD, hypertension mediated organ damage; LVH, left ventricular hypertrophy.

Guideline adherence to HMOD screenings

The adherence rates for basic screenings (spot urine UACR, ECG, and glomerular filtration rate [GFR]) were evaluated (Fig. 2). The adherence rate for basic screenings was significantly higher in the newly treated group than in the on-treatment group (74.8% vs. 57.1%, $P < 0.001$). The overall adherence rate of all basic screenings was 68.4%. GFR screening and ECG screening showed relatively high compliance across all groups, yielding overall compliance rate of 90.3% and 95.2%, respectively. For UACR screening, the adherence rate was significantly lower in the on-treatment group than in the newly treated group (59.1% vs. 79.9%, $P < 0.001$). Overall, adherence to UACR testing remained at 72.5%.

The rates of extended HMOD screening were also evaluated (Fig. 3). For TTE, screening rates were similar between the 2 groups (53.0% in the on-treatment group vs. 52.0% in the newly treated group), resulting in an overall compliance of 52.3%. Carotid ultrasonography and fundoscopic examination were performed infrequently, with overall rates of 12.3% and 22.1%, respectively. In contrast, ABI screening showed significantly higher compliance in the newly treated group than in the on-treatment group (79.1% vs. 54.3%, $P < 0.001$), yielding an overall rate of 70.2%. Similarly, baPWV screening was more frequently performed in the newly treated group (77.6% vs. 52.3%, $P < 0.001$), with an overall compliance rate of 68.5%.

Factors associated with adherence rate of basic screening and numbers of extended screenings

Factors influencing screening compliance were further evaluated. The associations between patient characteristics and the implementation of basic screenings were evaluated using univariate and multivariate logistic regression analyses (Table 2). Higher SBP emerged as an independent predictor of higher basic screening adherence tendency (OR, 1.19; 95% CI, 1.14 to 1.25; $P < 0.001$). Advancing age exhibited a significant trend of lower likelihood

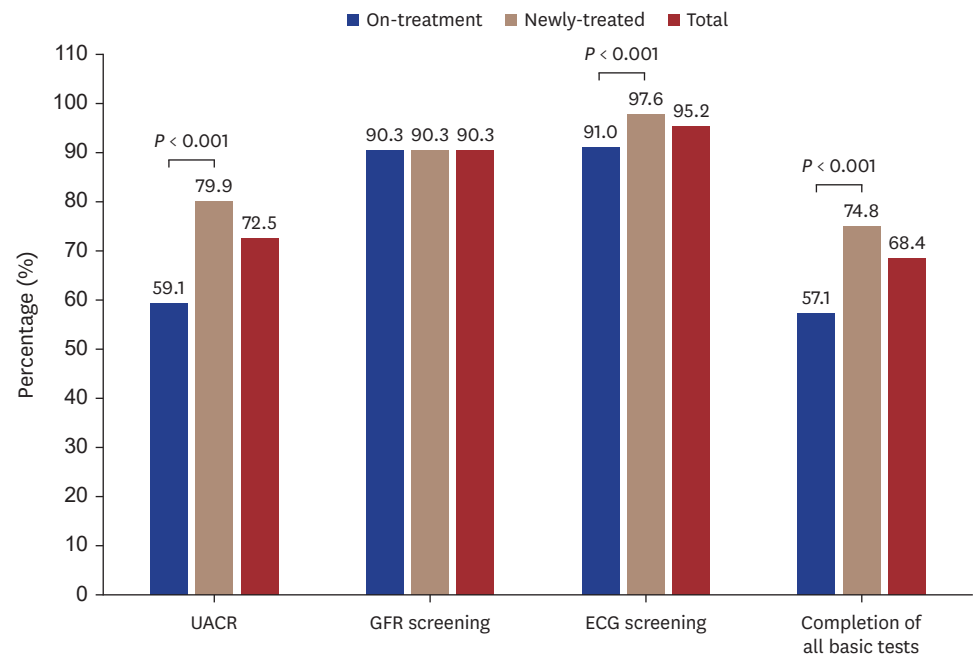


Fig. 2. Completion rates of basic hypertension mediated organ damage screening tests in on-treatment and newly treated patients. UACR, urine albumin-to-creatinine ratio; GFR, glomerular filtration rate; ECG, electrocardiography.

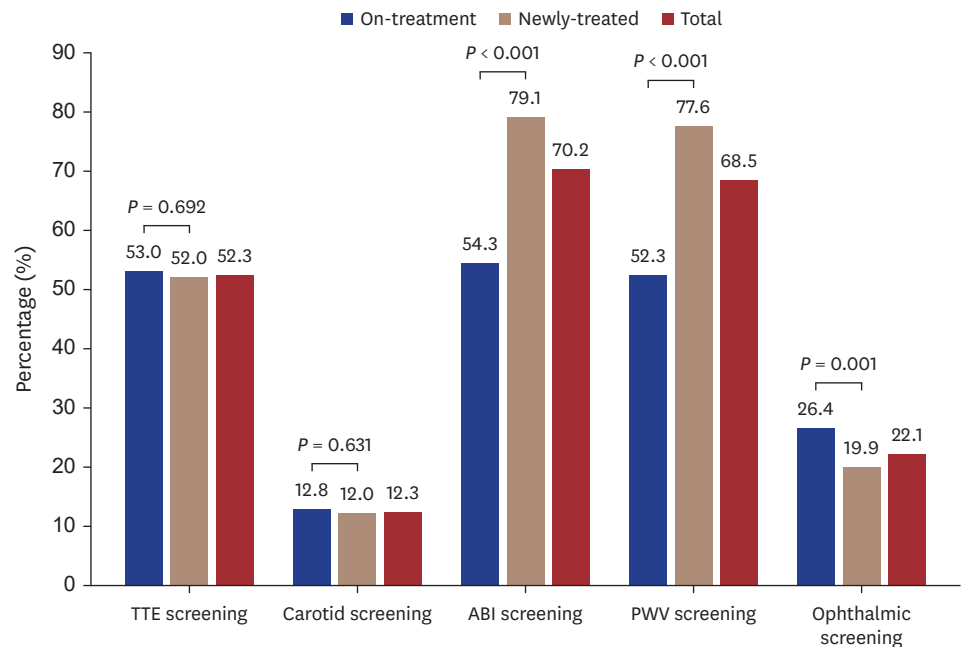


Fig. 3. Completion rates of extended hypertension mediated organ damage screening tests in on-treatment and newly treated patients.

TTE, transthoracic echocardiography; ABI, ankle-brachial index; PWV, pulse wave velocity.

of completing basic screenings in this analysis (OR, 0.91; 95% CI, 0.83 to 0.99; $P = 0.04$). In addition, presence of abdominal obesity (waist circumference of ≥ 90 cm in men and ≥ 85 cm in women) was significantly associated with higher compliance tendency of basic screening (OR, 1.38; 95% CI, 1.10 to 1.73; $P = 0.005$).

The associations between clinical and demographic factors and the number of extended screenings completed were analyzed using univariate and multivariate linear regression models (Table 3). In this analysis, abdominal obesity and higher SBP were positively associated with a greater number of screenings. In contrast, advancing age was significantly associated with fewer extended screenings.

Table 2. Logistic regression analysis model for factors that is associated with completion of basic hypertension mediated organ damage screening tests

	Univariate analysis			Multiple analysis		
	OR	95% CI	P-value	OR	95% CI	P-value
Intercept				0.28	0.11 to 0.68	0.006
Age per 10 yr	0.82	0.76 to 0.89	< 0.001	0.91	0.83 to 0.99	0.04
Male	1.22	0.93 to 1.35	0.24	1.04	0.85 to 1.28	0.73
BMI ≥ 25 kg/m ²	1.26	1.04 to 1.51	0.016	1.00	0.80 to 1.23	0.972
Abdominal obesity	1.26	1.27 to 1.88	< 0.001	1.38	1.10 to 1.73	0.005
SBP per 10 mmHg	1.22	1.17 to 1.28	< 0.001	1.19	1.14 to 1.25	< 0.001
Family history of early CVD	1.40	1.16 to 1.69	< 0.001	1.13	0.92 to 1.39	0.245
Current smoker	1.02	0.80 to 1.32	0.862	0.82	0.62 to 1.08	0.158
DM	0.78	0.59 to 1.05	0.096	0.94	0.69 to 1.29	0.709
Dyslipidemia	0.91	0.76 to 1.10	0.332	1.00	0.81 to 1.22	0.971
HTN duration	1.00	1.00 to 1.00	0.99			

OR, odd ratio; CI, confidence interval; BMI, body mass index; SBP, systolic blood pressure; CVD, cardiovascular disease; DM, diabetes mellitus; HTN, hypertension.

Table 3. Linear regression analysis model for factors associated with the number of performed extended hypertension-mediated organ damage screenings

	Univariate analysis			Multiple analysis		
	Beta	95% CI	P-value	Beta	95% CI	P-value
Intercept				1.65	1.21 to 2.09	< 0.001
Age per 10 yr	-0.15	-0.19 to -0.10	< 0.001	-0.09	-0.14 to -0.04	< 0.001
Male	0.02	-0.09 to 0.12	0.771	-0.10	-0.21 to 0.01	0.07
BMI ≥ 25 kg/m ²	0.23	0.12 to 0.33	< 0.001	0.11	-0.01 to 0.22	0.063
Abdominal obesity	0.24	0.13 to 0.34	< 0.001	0.14	0.02 to 0.25	0.023
SBP per 10 mmHg	0.09	0.07 to 0.11	< 0.001	0.07	0.05 to 0.09	< 0.001
Family history of early CVD	0.16	0.06 to 0.26	0.002	0.04	-0.06 to 0.15	0.478
Current smoker	0.18	0.04 to 0.32	0.011	0.09	-0.05 to 0.24	0.201
DM	0.04	-0.12 to 0.21	0.599	0.16	0.00 to 0.33	0.056
Dyslipidemia	-0.03	-0.16 to 0.07	0.522	-0.03	-0.14 to 0.07	0.522
HTN duration	0.00	0.00 to 0.00	0.277	0.00	0.00 to 0.00	0.272

CI, confidence interval; BMI, body mass index; SBP, systolic blood pressure; CVD, cardiovascular disease; DM, diabetes mellitus; HTN, hypertension.

HMOD screening according to age group.

Given that advancing age was associated with poorer screening compliance, basic screening rates were further evaluated according to age group (Fig. 4). Compliance rates for all basic screening tests differed significantly across age groups, with the highest rates observed in individuals aged < 40 years and the lowest in those aged ≥ 60 years (75.9% vs. 69.3% vs. 62.5%, *P* < 0.001). ECG and GFR screening rates remained high at approximately 90% across all age groups. In contrast, UACR screening showed a marked decline with increasing age (*P* < 0.001).

The number of extended HMOD screening tests performed differed significantly across age groups. The proportion of patients undergoing ≥ 2 extended HMOD screening tests declined significantly with advancing age, whereas the proportion undergoing 0–1 test was highest among those aged ≥ 60 years (*P* < 0.001) (Fig. 5).

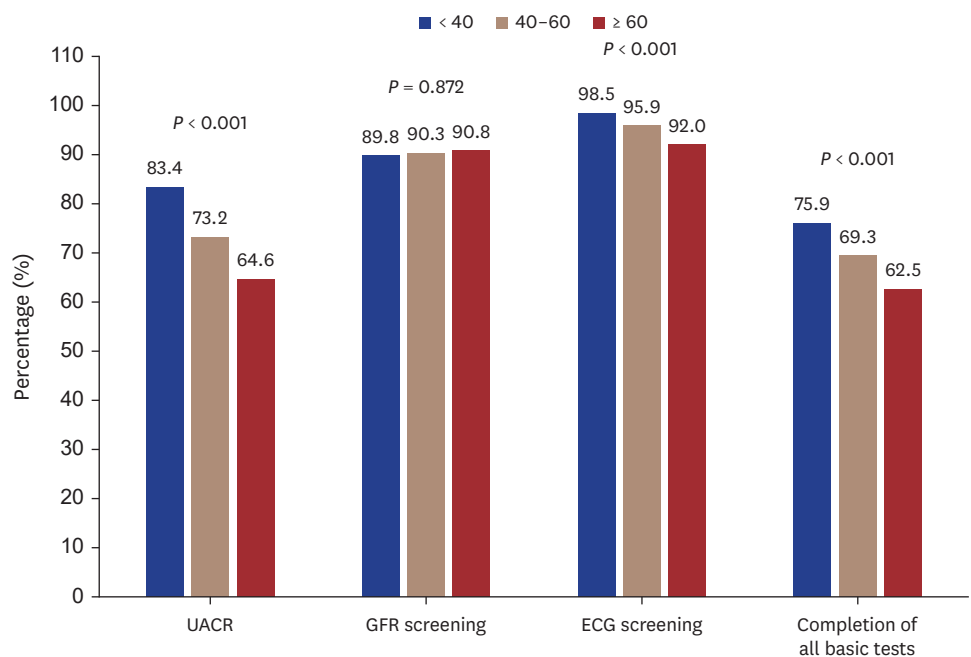


Fig. 4. Comparison of basic hypertension mediated organ damage screening tests by age group. UACR, urine albumin-to-creatinine ratio; GFR, glomerular filtration rate; ECG, electrocardiography.

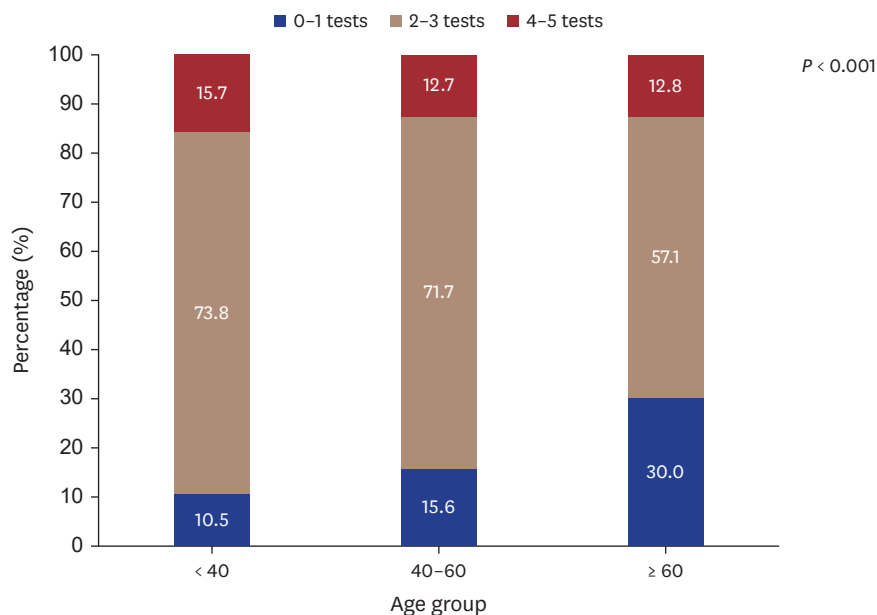


Fig. 5. The number of extended hypertension mediated organ damage screenings across age groups.

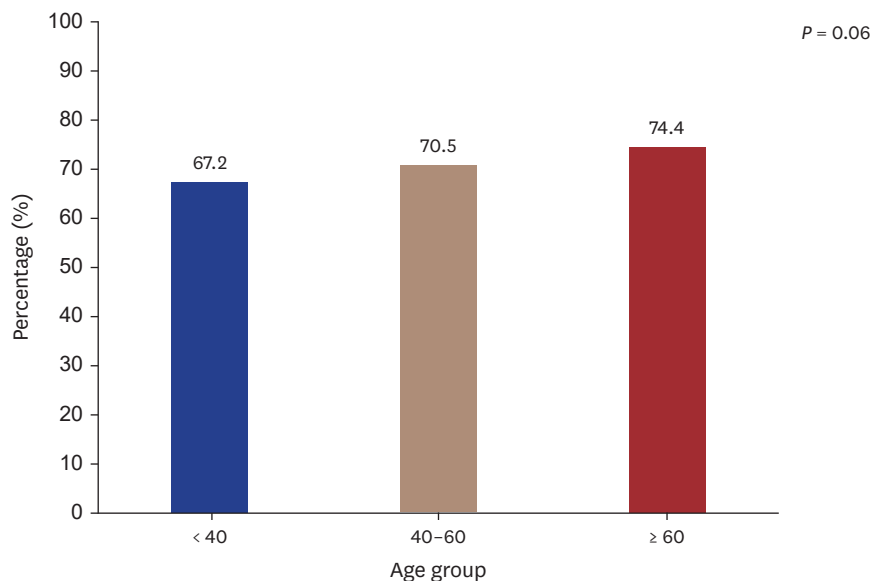


Fig. 6. Proportion of patients requiring strict blood pressure control (< 130/80 mmHg) stratified by age group.

Fig. 6 shows the proportion of individuals eligible for strict blood pressure control (< 130/80 mmHg) according to age group. Across the 3 age groups (< 40 years, 40–60 years, and ≥ 60 years), the proportions were 67.2%, 70.5%, and 74.4%, respectively, and the differences did not reach statistical significance ($P = 0.06$).

DISCUSSION

In this study, we evaluated real-world adherence to guideline-recommended HMOD screening among Korean hypertensive patients attending tertiary care centers.

The overall adherence rate for basic HMOD screening was 68.4%, indicating suboptimal implementation in routine clinical practice. Advancing age was significantly associated with a lower likelihood of undergoing both basic and extended screening tests. Consistently, adherence to HMOD screening was significantly lower among individuals aged ≥ 60 years.

Comprehensive risk assessment is crucial in HTN management [4,11] and contemporary guidelines for HTN consistently recommend HMOD screening for hypertensive patients [4,5,9,12,13]. Albuminuria is a well-established marker of kidney damage and an independent predictor of cardiovascular risk in hypertensive patients [4,13-15]. Based on this evidence, current guidelines recommend routine UACR for all hypertensive patients using a spot urine sample [3-5,15].

In this study, a major factor contributing to the low adherence rate of the basic assessment was the suboptimal utilization of the UACR. Our findings are consistent with those of previous studies. In the German 3A Registry, UACR was assessed in only 8.5% of hypertensive outpatients, whereas serum creatinine and ECG were performed in 99.6% and 59% of cases, respectively [6]. Similarly, in a nationwide Korean study evaluating adherence to HTN management guidelines from 2002 to 2016, the rate of UACR testing remained below 30% without meaningful improvement over time. In contrast, adherence to serum creatinine testing increased modestly from 39% to 59% during the same period [16]. Collectively, these observations suggest that UACR remains an underutilized component of HMOD assessment in real-world clinical practice.

Beyond its utility at the initiation of treatment, UACR can be a monitoring indicator during HTN management [4]. A previous study showed that patients with established cardiovascular risk experienced lower mortality with a 50% reduction in albuminuria, while an increase in albuminuria was associated with adverse cardiovascular outcomes [17]. Consequently, UACR is recommended throughout HTN management [4,18]. However, in this study, the adherence rate of UACR among on-treatment patients was 59.1%, which was significantly lower than that among newly treated patients. This finding reflects a substantial gap in the monitoring of HMOD. Because follow-up assessment of UACR provides valuable information on treatment response and evolving cardiovascular risk, its regular evaluation should be encouraged in routine clinical practice to achieve better long-term outcomes.

In addition to UACR, extended HMOD screening tests—including PWV, ABI, TTE, carotid ultrasound, and fundoscopic examination—were also underutilized in our study. Previous studies have demonstrated that intensified HMOD evaluation improves the identification of high-risk hypertensive individuals, enabling earlier recognition and intervention for those at elevated cardiovascular risk [6,11,19-21]. In one prior study, incorporating extended HMOD assessments such as TTE, carotid ultrasound, ABI, PWV, and ophthalmic examination reclassified 25.4% of patients initially categorized as having low or moderate risk into the high-risk group [11]. Given the relatively low implementation of extended HMOD screening in our study, it is plausible that some patients may have been misclassified as having a lower-than-appropriate risk level.

Given these findings, understanding the barriers to guideline adherence in HMOD screening is important for improving overall adherence. Several factors may account for the limited use of UACR, PWV, ABI, carotid ultrasound, and fundoscopic examinations [22]. First, these assessments require additional resources, which may reduce their practicality in real-world

clinical settings. Second, insufficient awareness of current guideline recommendations may hinder the consistent use of these tests. Third, some physicians may perceive these examinations as having limited impact on HTN management, which could contribute to the gap between guideline knowledge and actual practice patterns.

As a result, our findings highlight the need to strengthen dissemination efforts related to HMOD screening and to expand physician-education programs led by the KSH to improve adherence to guideline recommendations. Furthermore, these educational strategies should prioritize areas with the lowest adherence—particularly urine microalbumin testing and extended HMOD assessments—and emphasize the clinical relevance of comprehensive HMOD screening in improving real-world practice and patient outcomes. Additionally, implementing an electronic medical record–based clinical decision support alert that reminds physicians to perform urine microalbumin testing or extended HMOD evaluations may serve as a practical solution [22].

Contrary to the fact that the prevalence of HMOD increases with age [23], the completion rate of HMOD evaluation was lowest among patients aged ≥ 60 years. The lack of thorough screening may explain why the proportion of older adults identified as candidates for strict blood pressure control ($< 130/80$ mmHg) did not differ significantly from that of younger cohorts in this study. Our findings raise concerns that underutilization of HMOD screening in older patients may lead to under-detection of HMOD in this high-risk population, potentially resulting in missed opportunities for optimal management. This issue is particularly relevant in light of the SPRINT and STEP trials, which demonstrated significant benefits of intensive blood pressure control [24-26]. Taken together, insufficient HMOD evaluation in older patients may increase the risk of adverse clinical outcomes by delaying or limiting timely therapeutic interventions.

Despite widespread awareness of HTN guidelines among physicians, their implementation in real-world practice remains suboptimal [27]. One possible explanation for the lower adherence observed in older patients is their frequent presentation with multiple comorbidities. These comorbid conditions may complicate the implementation of guideline-recommended assessments and limit tolerance for multiple diagnostic procedures [6,28].

In addition, structural characteristics of the South Korean healthcare system may contribute to lower adherence to HMOD screening guidelines. Despite the overall high quality and accessibility of care in South Korea, the system is characterized by extremely low reimbursement rates, resulting in a substantial consultation burden on physicians [29]. The combined impact of low reimbursement rates and high consultation volumes may limit physicians' ability to devote sufficient time to comprehensive guideline-recommended assessments. Addressing this issue will require systemic changes. First, reimbursement structures should be revised to more accurately reflect the costs and resources associated with comprehensive HTN management. Second, adopting a team-based care model involving nurses and clinical pharmacists may enhance the overall quality of HTN management and facilitate the delivery of guideline-recommended care [30].

This study has several limitations. First, it was conducted at tertiary care centers, which may limit the generalizability of our findings to other populations, particularly those managed in primary or community care settings. Second, because this was a prospective study, the performance rate of HMOD screening may have been overestimated compared with

routine clinical practice. Third, we did not evaluate long-term clinical outcomes; therefore, we were unable to assess the association between adherence to HMOD screening guidelines and patient prognosis. Finally, we did not account for socioeconomic status, which may influence screening adherence and potentially affect the interpretation of our findings.

CONCLUSIONS

In conclusion, guideline-recommended HMOD screening remains underutilized in routine clinical practice. The overall completion rate for basic screening was suboptimal, with significantly lower rates observed among older patients. Moreover, adherence to basic screening was lower in patients receiving ongoing treatment than in newly treated patients. These findings indicate that comprehensive risk assessment is insufficiently implemented in hypertensive patients, particularly during long-term management. Improving adherence to HMOD screening guidelines is essential to optimize risk stratification and improve clinical outcomes.

SUPPLEMENTARY MATERIAL

Supplementary Table 1

Participating institutions and IRB approval numbers

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