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ORIGINAL RESEARCH

Hemodynamic-Guided Therapy is Associated with Better Hypertension Control Compared with Standard Care: A Comparative Clinical Analysis

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Background: Blood pressure abnormalities are common in patients with heart-related conditions and substantially increase morbidity and mortality. This retrospective comparative study evaluated the value of a hemodynamic-guided therapy (HGT) intervention on systolic and diastolic blood pressure (SBP, DBP) compared with standard care.

Methods: We retrospectively analyzed 156 patients with cardiovascular disease (HGT, n = 107; control, n = 49). SBP and DBP were measured at baseline and after treatment using standardized noninvasive hemodynamic monitoring. Hemodynamic parameters (including cardiac output, systemic vascular resistance, and total body fluids were used to guide medication selection and titration in the HGT group. Normality of paired difference scores was assessed with the Shapiro–Wilk test, and within-group comparisons were performed with paired t-tests. Categorical comparisons used chi-square tests. Statistical significance was set at two-sided $p < 0.05$.

Results: Post-treatment assessments showed significant reductions in both SBP and DBP in the HGT group but not in the control group. Among women receiving HGT, the mean post-treatment SBP was 133.8 mmHg (baseline to post-treatment change, $p < 0.001$); among men receiving HGT, the mean post-treatment SBP was 131.6 mmHg versus 150.5 mmHg at baseline ($p < 0.001$). DBP in women receiving HGT decreased to a mean of 74.2 mmHg, and in men to 74.7 mmHg from 85.5 mmHg at baseline (both $p < 0.001$). No significant SBP or DBP changes were observed in the control arm.

Conclusion: In this retrospective analysis, hemodynamic-guided therapy was associated with significant improvements in systolic and diastolic blood pressure compared with standard care. Using individualized hemodynamic profiles to guide medication selection and dosing may improve blood pressure control in patients with hypertension and cardiovascular comorbidities; prospective studies are warranted to confirm these findings.

Keywords: hemodynamics, comparative analysis, hypertension, blood pressure, hemodynamic guided therapy

Introduction

Cardiovascular disease (CVD) represents a major healthcare challenge globally, affecting millions of individuals, particularly in middle- and low-income countries. This condition is associated with significant health risks, notably an increased susceptibility to severe events such as heart disease and stroke.[1] Global estimates show that CVD, encompassing heart attack, stroke, and heart failure, accounted for 19.2 million deaths in 2023, representing roughly one in three global deaths, a sharp rise from 13.1 million in 1990.[2] While age-standardized mortality rates have declined in some high-income settings, the absolute number of people affected has increased due to population growth and aging.[3] The burden is disproportionately concentrated in low- and middle-income countries (LMICs), where over 75% of the global CVD burden lies.[4,5]

In Taiwan, heart-related conditions are particularly prevalent, as indicated by substantial rates among the population, which include coronary artery disease, heart attacks, arrhythmias, heart failure, stroke, peripheral artery disease, and endocarditis.[6,7]

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Hypertension, a critical risk factor for these conditions, remains alarmingly common, with reports indicating that over 60% of patients with heart-related issues are affected.[7] It frequently clusters with other metabolic and behavioral risk factors, such as obesity and diabetes, which synergistically amplify cardiovascular risk and complicate management.[8] This highlights the urgent need for effective hypertension management strategies.

The epidemiological landscape of hypertension presents distinct challenges across income levels. In LMICs, high rates of urbanization are associated with higher hypertension prevalence compared to rural areas.[9] Moreover, in these resource-constrained settings, awareness, treatment, and control rates are alarmingly low; for instance, in 2019, nearly half of those with hypertension were undiagnosed, and over 700 million people were not receiving necessary treatment.[10] In Taiwan, while age-standardized CVD mortality has decreased, the incidence of stroke and acute myocardial infarction has plateaued or increased, reflecting improved survival but also a persistent high burden of established CVD.[11] National data show that approximately 25% of the Taiwanese population has hypertension, with significant room for improvement in achieving optimal control targets.

Beyond population statistics, clinical practice increasingly recognizes that hemodynamic heterogeneity differences in arterial stiffness, systemic vascular resistance (SVR), and cardiac output (CO) influence both cardiovascular risk and therapeutic response.[12] Therefore, implementing targeted treatment strategies guided by hemodynamic assessment is essential for optimizing patient outcomes. In developing nations, the challenge associated with hypertension management is particularly pronounced, where healthcare resources may be limited, yet the prevalence of hypertension poses a considerable burden on healthcare systems.[13] Recent evidence suggests that selecting antihypertensive therapy based on an individual's hemodynamic profile may lead to more effective blood pressure control than standard care alone, particularly in patients with uncontrolled hypertension.[12] Nevertheless, prior studies have been heterogeneous in patient selection, small in sample size, and limited in representation of patients with established cardiovascular comorbidities or from middle-income health systems, leaving a gap in real-world comparative data on the effectiveness of hemodynamic-guided decision-making.

The objective of this retrospective comparative study was to evaluate whether an HGT approach improves systolic and diastolic blood pressure control compared with standard care among patients with established cardiovascular disease. We hypothesized that HGT, by guiding medication selection and dose titration based on individual hemodynamic profiles, would improve hypertension management (CO, SVR, Body fluids) and arterial compliance will produce greater reductions in SBP and DBP than standard management alone, hence, contributing evidence to support personalized hypertension management in clinical practice.[14]

Materials and Methods

Study Design

This study employed a retrospective cohort design to assess the impact of HGT on blood pressure control among patients with heart-related conditions. Patients were categorized into two groups: cases, comprising individuals who received HGT, and controls, representing those who did not receive such guided therapy. The study compared baseline and subsequent blood pressure measurements between the two groups to evaluate the effectiveness of HGT in improving systolic and diastolic blood pressure.

Study Population

The study population consisted of 156 patients with HT and heart-related conditions (including but not limited to coronary artery disease, myocarditis, myocardial infarction, and heart failure) who received treatment at Chung Shan Medical University Hospital between 2021 and 2022. Patients were recruited based on their medical records and history of multiple hospital visits. Inclusion criteria included individuals with documented heart-related conditions and a history of at least three hospital visits, during which blood pressure measures were recorded. Two individuals were excluded due to incomplete medical records.

Study Design and Follow-Up Procedure

Patients with chronic hypertension were randomly assigned to either an HGT group or a standard care control group. At the baseline visit, SBP and DBP were recorded for all participants. In the HGT group, noninvasive hemodynamic assessment was performed during the same visit using the ICON® Hemodynamic Monitor (Osypka Medical, Berlin, Germany), and

antihypertensive therapy was adjusted accordingly. Control group patients received medication adjustments based on routine clinical assessment as usual.

Participants returned for follow-up after 3–4 weeks, allowing sufficient time for medication effects to stabilize and for washout of prior medications. The SBP and DBP measured at this visit were used as the post-intervention values, reflecting short-term treatment response. A subsequent visit occurred approximately four weeks later for further dose optimization, after which patients with controlled blood pressure were monitored at approximately two-month intervals.

Intervention

Among the recruited patients, 107 individuals received HGT, referred to as the case group, while the remaining patients (n =49) served as controls, receiving standard care without hemodynamic guidance. For the case group, we utilized [ICON®, Osypka Medical, Berlin, Germany], a non-invasive, real-time hemodynamic monitoring system. This advanced technology allowed for continuous monitoring and recording of critical hemodynamic parameters, providing immediate and clinically relevant insights into the patients' cardiovascular status. The non-invasive nature of this device, combined with its quick, easy real-time data output, facilitated frequent and accurate assessments without causing discomfort or risk to the patients. This approach enabled individualized fluid and pharmacologic management tailored to each patient's dynamic hemodynamic status. The specific hemodynamic parameters included SVR, SV, CO, cardiac contractility (ICON), and Thoracic Fluid Content (TFC), "which represents chest congestion", were monitored and recorded for the case group during their hospital visits. In contrast, the control group received standard care without the hemodynamic guidance, relying instead on standard clinical assessments and routine interventions.

Notably, hemodynamics allowed us to "treat pathophysiology" and the root cause rather than focusing only on blood pressure and heart rate. ICON® provided real-time measures or parameters mentioned above. Each parameter was interpreted to identify the underlying physiological cause of abnormal blood pressure or symptoms and guide a specific therapeutic pathway. For example, when elevated SVR was identified, it indicated excessive vascular constriction. In such cases, vasodilator therapy was prioritized rather than simply increasing other antihypertensive agents. Next, when the TFC was elevated, indicating fluid overload, diuretic therapy was initiated or adjusted, and dosing was titrated based on objective response rather than clinical assessment alone. Conversely, when low TFC suggested volume depletion, diuretic therapy was reduced or adjusted accordingly. Additionally, if the CO and heart contractility were high, we may initiate (B-Blocker), and if they were low, we focused on optimizing the B-Blocker dose, or considered discontinuing it (if there was no tachycardia) when appropriate.

Data Collection

For each participant, we extracted baseline demographic, clinical, and treatment variables from the electronic medical record. Blood pressure measurements, including SBP and DBP, were recorded at baseline and subsequent hospital visits for both cases and controls (after 5 minutes of complete rest). Hemodynamic parameters (SVR, SV, CO, ICON, and TFC were also measured and documented for the case group during each visit. Variables collected included age at index date (years), sex (male/female), body mass index (BMI; kg/m^2) where height and weight were available, smoking status (current/never), and other disease status (diabetes mellitus, renal disease, and cardiovascular disease).

Statistical Analysis

All analyses were performed using the R statistical software (version 4.2.0). Descriptive statistics summarized the study population's baseline characteristics and hemodynamic parameters. Within-group comparisons of baseline and post-treatment SBP were assessed with paired t-tests after verifying the normality of the differences using the Shapiro–Wilk test. Between-group comparisons of categorical SBP categories were conducted with chi-square tests. Results are presented as counts (n) and percentages (%) for categorical variables and as mean and standard deviation (SD) for continuous variables. Statistical significance was set at $p < 0.05$. Box plots were generated (using the ggplot2 version 3.4.4) to display the median, interquartile range (IQR), whiskers extending to 1.5 times the IQR, and individual data points indicating outliers. Separate plots were created for pre- and post-intervention systolic and diastolic blood pressure measurements within each treatment group.

Ethical Considerations

This study was conducted following the Declaration of Helsinki Ethical Principles and was approved by the Institutional Review Board (IRB) of Chung Shan Medical Hospital (CS2-18089). Informed consent was obtained from all participants before data collection.

Results

Table 1 summarizes the distribution of patients based on their receipt of HGT. Among the study population of 156 hypertension patients with heart-related conditions, 107 individuals received HGT (cases), while 49 did not (controls). The majority of cases were aged 55 years and above. A majority of participants were men (73.47% for controls and 77.57% for cases), and a substantial proportion presented with obesity (BMI ≥27; 51.02% and 53.27%). Furthermore, no significant intergroup differences were observed in the prevalence of smoking (18.37% and 18.69%), coronary artery disease (CAD; 46.94% and 53.27%), diabetes mellitus (DM; 48.98% and 53.27%), or renal disease (34.69% and 34.58%), suggesting a comparable baseline health status across the study cohorts ($p < 0.05$ for all comparisons).

Baseline and post-treatment SBP measurements are presented in Table 2. In the control group, there were no significant differences observed between baseline and post- treatment SBP values for both men and women (162.8 mmHg vs. 152.3 mmHg in men, 157.1 mmHg vs. 153.5 mmHg in women, $p<0.05$). Conversely, among individuals who received HGT, significant reductions in SBP were noted from baseline to post-treatment measurements, with values of 157.3 mmHg vs. 133.8 mmHg in women ($p<0.001$) and 150.5 mmHg vs. 131.6 mmHg in men ($p<0.001$). Notably, cases with coronary artery disease (CAD) who received HGT exhibited significantly decreased SBP compared to baseline values (151.3 mmHg vs. 131.4 mmHg, $p<0.001$), while no significant change was observed in the control group (157.6 mmHg vs. 150.5 mmHg, $p = 0.106$).

These findings underscore the efficacy of HGT in reducing SBP across various subgroups, particularly in individuals with CAD.

Table 1 General Features of Study Patients (n = 156) Presented as Counts (n), and Percentages (%)

Features	No Hemodynamic-Guided Therapy (n=49)	Hemodynamic-Guided Therapy (n=107)	p-value
Baseline SBP (mmHg)			0.434
Normal (≤120)	0 (0.00%)	3 (2.80%)	
Elevated (121–140)	6 (12.24%)	16 (14.95%)	
High (≥141)	43 (87.76%)	88 (82.24%)	
Post-SBP (mmHg)			<0.001
Normal (≤120)	0 (0.00%)	14 (13.08%)	
Elevated (121–140)	7 (14.29%)	70 (65.42%)	
High (≥141)	42 (85.71%)	23 (46.94%)	
Baseline DBP (mmHg)			<0.001
Normal (≤80)	2 (4.08%)	42 (39.25%)	
Elevated (81–90)	7 (14.29%)	29 (27.10%)	
High (≥91)	40 (81.63%)	36 (33.64%)	
Post-DBP (mmHg)			<0.001
Normal (≤80)	6 (12.24%)	73 (68.22%)	
Elevated (81–90)	13 (26.53%)	25 (23.36%)	
High (≥91)	30 (61.22%)	9 (8.41%)	
Gender, n (%)			0.722
Women	13 (26.53%)	24 (22.43%)	
Men	36 (73.47%)	83 (77.57%)	
Age, years, n (%)			0.128
<55 y/o	18 (36.73%)	26 (24.30%)	
56–66 y/o	9 (18.37%)	30 (28.04%)	
67–73 y/o	14 (28.57%)	22 (20.56%)	
>73 y/o	8 (16.33%)	29 (27.10%)	

(*Continued*)

Table 1 (Continued).

Features	No Hemodynamic-Guided Therapy (n=49)	Hemodynamic-Guided Therapy (n=107)	p-value
BMI, n (%)			0.369
Underweight (<18.5 kg/m^2)	0 (0.00%)	1 (1.00%)	
Normal (18.5–23.9 kg/m^2)	13 (26.53%)	17 (15.89%)	
Overweight (24–26.9 kg/m^2)	11 (22.45%)	32 (29.91%)	
Obesity (≥27 kg/m^2)	25 (51.02%)	57 (53.27%)	
Smoking, n (%)			1.000
No	40 (81.63%)	87 (81.31%)	
Yes	9 (18.37%)	20 (18.69%)	
CAD, n (%)			0.574
No	26 (53.06%)	50 (46.73%)	
Yes	23 (46.94%)	57 (53.27%)	
DM, n (%)			0.745
No	25 (51.02%)	50 (46.73%)	
Yes	24 (48.98%)	57 (53.27%)	
Renal Diseases, n (%)			1.000
No	32 (65.31%)	70 (65.42%)	
Yes	17 (34.69%)	37 (34.58%)	

Abbreviations: SBP, systolic blood pressure; DBP, diastolic blood pressure; CAD, coronary artery disease; DM, diabetes mellitus; BMI, body mass index.

Table 2 Baseline and Post-Treatment Systolic Blood Pressure (SBP) Values for Patients in the Non-Hemodynamic (n = 49) and Hemodynamic-Guided Therapy (HGT; n = 107) Arms Based on the t-Test and Chi-Square Test

	No Hemodynamic-Guided Therapy			Hemodynamic Guided Therapy		
	Baseline-SBP	**Post-SBP**	**p-value**	**Baseline SBP**	**Post-SBP**	**p-value**
Gender						
Women	162.8 (14.0)	152.3 (12.3)	0.073	157.3 (8.4)	133.8 (13.4)	<0.001
Men	157.1 (14.0)	153.5 (13.1)	0.211	150.5 (15.7)	131.6 (11.5)	<0.001
Age						
<55 y/o	151.2 (12.4)	147.6 (6.9)	0.234	150.1 (14.9)	130.3 (11.4)	<0.001
56–66 y/o	152.2 (8.3)	155.8 (11.3)	0.272	150.3 (12.8)	130.9 (13.6)	<0.001
67–73 y/o	171.1 (12.4)	155.4 (16.9)	0.030	153.3 (8.7)	135.8 (10.6)	<0.001
>73 y/o	160.8 (10.8)	159.0 (14.2)	0.768	154.5 (19.2)	132.2 (11.6)	<0.001
BMI						
Underweight	NaN (NA)	NaN (NA)	–	148.0 (NA)	152.0 (NA)	–
Normal	163.8 (13.1)	166.0 (15.3)	0.697	152.7 (7.6)	132.6 (12.3)	<0.001
Overweight	153.0 (12.3)	148.6 (6.4)	0.250	156.6 (13.8)	129.7 (10.8)	<0.001
Obesity	158.4 (14.8)	148.5 (8.7)	0.012	149.3 (16.2)	133.0 (12.3)	<0.001
Smoking						
No	158.7 (13.5)	154.8 (13.4)	0.157	152.9 (14.4)	132.1 (12.6)	<0.001
Yes	158.4 (17.3)	146.2 (6.6)	0.100	148.0 (15.3)	132.1 (8.8)	0.001
CAD						
No	159.5 (11.8)	155.5 (13.6)	0.202	152.8 (15.9)	132.9 (12.5)	<0.001
Yes	157.6 (16.6)	150.5 (11.6)	0.106	151.3 (13.5)	131.4 (11.5)	<0.001

(*Continued*)

Table 2 (Continued).

	No Hemodynamic-Guided Therapy			Hemodynamic Guided Therapy		
	Baseline-SBP	**Post-SBP**	**p-value**	**Baseline SBP**	**Post-SBP**	**p-value**
DM						
No	160.9 (14.9)	152.0 (13.3)	0.030	153.5 (16.0)	132.1 (11.1)	<0.001
Yes	156.3 (13.1)	154.5 (12.5)	0.574	150.7 (13.2)	132.1 (12.8)	<0.001
Renal Diseases						
No	156.7 (14.0)	151.9 (13.0)	0.118	151.8 (15.0)	132.8 (11.5)	<0.001
Yes	162.2 (13.9)	155.6 (12.6)	0.182	152.5 (14.1)	130.7 (12.8)	<0.001

Notes: Values are shown as mean (SD), and the p-value tests whether SBP changed significantly from baseline to post-treatment within each subgroup.
Abbreviations: SBP, systolic blood pressure; DBP, diastolic blood pressure; CAD, coronary artery disease; DM, diabetes mellitus; BMI, body mass index; NaN, not a number; SD, Standard deviation.

Analysis of DBP revealed significant reductions in post-intervention DBP among individuals receiving HGT, irrespective of gender (Table 3). Specifically, post-treatment DBP values were significantly lower compared to baseline measurements in both women (74.2 ± 12.4 mmHg vs. 79.7 ± 10.0 mmHg, $p = 0.033$) and men (74.7 ± 12.5 mmHg vs. 85.5 ± 14.3 mmHg, $p < 0.001$). In

Table 3 Baseline and Post-Treatment Diastolic Blood Pressure (DBP) Values for Patients in the Non-Hemodynamic (n = 49) and Hemodynamic-Guided Therapy (HGT; n = 107) Arms Based on the t-Test and Chi-Square Test

	No Hemodynamic-Guided Therapy			Hemodynamic Guided Therapy		
	Baseline DBP	**Post-DBP**	**p-value**	**Baseline DBP**	**Post-DBP**	**p-value**
Gender						
Women	94.3 (8.8)	90.5 (14.4)	0.262	79. 7 (10.0)	74.2 (12.4)	0.033
Men	97.9 (10.9)	92.0 (8.1)	0.003	85.5 (14.3)	74.7 (12.5)	<0.001
Age						
<55 y/o	94.0 (11.1)	90.5 (8.8)	0.114	95.3 (10.4)	81.34 (10.8)	<0.001
56–66 y/o	92.4 (3.6)	92. 8 (4.2)	0.893	87.0 (11.1)	77.6 (11.3)	<0.001
67–73 y/o	103.1 (10.0)	94.4 (10.0)	0.026	80.1 (12.2)	75.7 (10.0)	0.049
>73 y/o	95.6 (11.0)	88.1 (16.1)	0.073	74.3 (11.6)	64.5 (10.7)	<0.001
BMI						
Underweight	NaN (NA)	NaN (NA)	–	68.0 (NA)	85.0 (NA)	–
Normal	97.7 (11.6)	88.2 (13.7)	0.005	80.7 (14.4)	69.5 (15.4)	0.003
Overweight	93.4 (3.6)	93.6 (5. 7)	0.886	81.9 (12.0)	71.3 (10.6)	<0.001
Obese	97.4 (11.7)	92.5 (9.12)	0.040	86.8 (13.9)	77.8 (11.7)	<0.001
Smoking						
No	96.0 (10.6)	91.7 (11.1)	0.015	84.3 (13.8)	75.1 (12.7)	<0.001
Yes	99.2 (9.2)	91.3 (2.1)	0.038	83.5 (13.5)	72.4 (11.1)	<0.001
CAD						
No	96.9 (12.1)	90.5 (12.1)	0.005	85.2 (12.5)	76.5 (12.5)	<0.001
Yes	96.2 (8.3)	93.0 (7.0)	0.138	83.2 (14.6)	72.9 (12.2)	<0.001
DM						
No	97.6 (12.6)	93.1 (11.1)	0.059	86.8 (14.0)	76.2 (12.8)	<0.001
Yes	95.5 (7.53)	90.1 (8.7)	0.011	81.8 (13.0)	73.2 (12.1)	<0.001
Renal Diseases						
No	95.6 (12.1)	91.4 (11.6)	0.057	85.4 (13.0)	76.3 (12.1)	<0.001
Yes	98.4 (5.8)	92.1 (6.3)	0.001	81.8 (14.6)	71.4 (12.6)	<0.001

Notes: Values are shown as mean (SD), and the p-value tests whether SBP changed significantly from baseline to post-treatment within each subgroup.
Abbreviations: SBP, systolic blood pressure; DBP, diastolic blood pressure; CAD, coronary artery disease; DM, diabetes mellitus; BMI, body mass index; NaN, not a Number.

contrast, among individuals without HGT, only men exhibited a statistically significant, albeit smaller, reduction in DBP (92.0 ± 8.1 mmHg vs. 97.9 ± 10.9 mmHg, p = 0.003), while no significant difference was observed in women (90.5 ± 14.4 mmHg vs. 94.3 ± 8.8 mmHg, p = 0.262). Furthermore, patients with CAD who received HGT demonstrated a significant decrease in DBP from baseline to post-intervention (72.9 ± 12.2 mmHg vs. 83.2 ± 14.6 mmHg, p < 0.001). These results further support the beneficial impact of HGT on blood pressure management across various patient subgroups.

In this study, we evaluated blood pressure control in heart-related patients managed with or without non-invasive hemodynamic monitor-guided medication selection and adjustments. Analysis of the overall cohort demonstrated that the mean SBP decreased from 154.09 mmHg to 138.73 mmHg, while the mean DBP decreased from 88.06 mmHg to 79.94 mmHg following hemodynamic-guided treatment. Subgroup analysis revealed that patients who received hemodynamic-guided care achieved a more substantial reduction in blood pressure compared to those under standard management. In the hemodynamic care group, SBP decreased from 152.02 mmHg to 132.11 mmHg, and DBP decreased from 84.17 mmHg to 74.58 mmHg. In contrast, the standard care group exhibited only a modest decline, with SBP decreasing from 158.61 mmHg to 153.18 mmHg and DBP from 96.57 mmHg to 91.63 mmHg. Furthermore, boxplot analyses (Figure 1) indicated that the

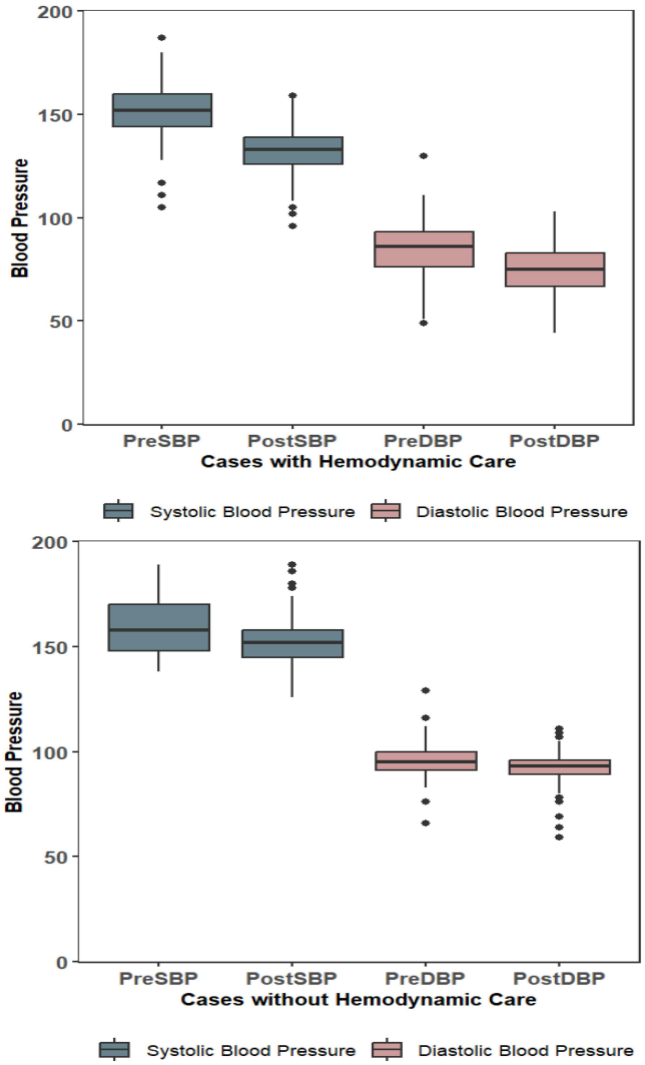

Figure 1 Box plots showing systolic blood pressure (SBP, blue) and diastolic blood pressure (DBP, red) measurements at baseline (PreSBP, PreDBP) and post-intervention (PostSBP, PostDBP) in patients receiving hemodynamic-guided therapy (top panel) and those without hemodynamic-guided therapy (bottom panel).

Note: Boxes represent the interquartile range (IQR), horizontal lines indicate the median, whiskers extend to 1.5 times the IQR, and dots represent outliers. Paired comparisons between pre- and post-intervention blood pressure values were analyzed using the Wilcoxon signed-rank test. In the hemodynamic-guided group, both SBP and DBP showed significant reductions after treatment (p < 0.001). In contrast, patients without hemodynamic guidance did not demonstrate statistically significant changes in blood pressure (p > 0.05).

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hemodynamic-guided group demonstrated a narrower distribution and fewer extreme outliers in blood pressure measurements, suggesting more consistent and stable blood pressure control. These findings collectively indicate that non-invasive hemodynamic monitoring facilitates more effective and individualized blood pressure management, leading to improved cardiovascular stability and reduced variability in patients with heart-related conditions.

Discussion

In this retrospective analysis of hypertension patients with cardiovascular comorbidities in Taiwan, we observed that those managed with HGT had statistically significant reductions in both SBP and DBP from baseline. Reductions were seen across age groups and were particularly notable among patients with CAD. These findings are consistent with the hypothesis that individualized treatment guided by hemodynamic parameters can help optimize antihypertensive strategies in complex patients.

Hypertension arises from multiple interacting hemodynamic factors, including CO, SVR, and circulating volume.[15–17] However, achieving normal blood pressure with antihypertensive drugs remains challenging due to several factors, including underlying pathophysiology, individual variability in drug response, potential side effects impacting treatment adherence, the need for multiple medications leading to polypharmacy, cost and accessibility issues, masked hypertension, white coat hypertension, and the possibility of resistant hypertension, these challenges highlight the need for personalized treatment approaches tailored to each patient's specific clinical profile.

HGT aims to characterize these contributing factors using direct or derived hemodynamic metrics (for example, stroke volume, CO, SVR, and body fluids) and to tailor therapy accordingly. This approach may lead to more targeted selection of vasodilators, diuretics, or agents affecting cardiac contractility, thereby improving blood pressure control in patients whose hypertension is driven by non-uniform pathophysiology. Previous studies and proof-of-concept trials have suggested that hemodynamic-guided approaches can improve blood pressure control and reduce medication burden in selected populations.[18,19] Our results generally align with these reports in demonstrating blood pressure reductions with HGT, and extend them by demonstrating effectiveness across an older, cardiovascular-comorbid cohort, including patients with CAD. However, the magnitude and durability of effect have varied across studies, likely reflecting differences in patient selection, monitoring technology, treatment algorithms, and follow-up duration. Where possible, direct comparison with randomized trials remains limited: our nonrandomized, retrospective design does not allow firm conclusions regarding superiority over standard specialist care.

We found higher baseline SBP and DBP among men in both treatment arms, and a greater mean reduction after therapy among women. Sex differences in antihypertensive response have been described previously and may relate to differences in vascular stiffness, hormonal influences, body composition, and treatment adherence. These exploratory subgroup findings warrant cautious interpretation and should be tested in future prospective studies designed to evaluate sex-specific responses.

HGT leverages advanced monitoring technologies to assess real-time hemodynamic parameters, such as cardiac output, systemic vascular resistance, body fluids, and central venous pressure.[20] By continuously evaluating these parameters, healthcare providers can obtain a comprehensive understanding of a patient's cardiovascular status and tailor treatment strategies accordingly. This personalized approach allows for timely adjustments in medication regimens, fluid management, and lifestyle interventions, optimizing blood pressure control and mitigating the risk of cardiovascular events. Despite the benefits associated with HGT, its effectiveness in achieving normal blood pressure across diverse patient populations remains to be fully elucidated.

To evaluate the efficacy of HGT in hypertension control, comparisons with standard specialist care are essential. While specialist care typically involves regular clinic visits and routine blood pressure measurements, it may lack the dynamic monitoring capabilities offered by hemodynamics-guided approaches. By directly assessing hemodynamic parameters, HGT provides a more comprehensive evaluation of cardiovascular function, enabling proactive interventions to address underlying hemodynamic imbalances and optimize blood pressure management.

Despite the promising findings, several limitations should be acknowledged. First, the retrospective and nonrandomized design means our results demonstrate an association but cannot establish causation. Treatment allocation bias and clinician preference may have influenced both selection for HGT and treatment intensity. Second, selection bias is possible, as patients referred for HGT may differ systematically from controls in ways not captured by the available data,

such as disease severity, prior treatment failures, or health-seeking behavior. Third, unmeasured confounding remains a concern. Variables such as medication adherence, lifestyle changes, socioeconomic factors, concurrent therapies, and clinician decision-making were not fully captured and may account for part of the observed differences. Fourth, the sample size and follow-up duration were limited, restricting power for subgroup analyses and precluding assessment of long-term clinical outcomes (cardiovascular events, hospitalizations, mortality). Fifth, heterogeneity in HGT implementation (eg., different devices, monitoring frequencies, and treatment algorithms) and variability in usual-care practices may limit generalizability. Next, the study primarily evaluated short-term blood pressure control, as the primary post-intervention measurement was obtained 3–4 weeks after treatment adjustment. Although this interval allows adequate time for antihypertensive medications to reach therapeutic effect, it may not fully capture long-term blood pressure stability or sustained treatment adherence. Additionally, a higher proportion of men in both study arms and an imbalance in sex distribution between groups may limit the ability to perform reliable sex-specific comparisons or to evaluate sex as an effect modifier of the intervention. Future studies should ensure balanced enrollment or prespecify stratified analyses to assess whether treatment effects differ by sex. Finally, the study relied on clinic blood pressure measurements and did not consistently include ambulatory or home blood pressure monitoring, which may affect measurement reliability. Finally, future prospective randomized controlled studies with longer follow-up durations and standardized treatment protocols are warranted to further evaluate the long-term impact of hemodynamic-guided therapy on cardiovascular outcomes and patient-centered endpoints.

Despite these limitations, our findings support the potential utility of hemodynamic information in guiding individualized antihypertensive therapy, particularly in older patients with cardiovascular comorbidities. To build on these results, prospective randomized controlled trials are needed to compare HGT with guideline-based usual care using standardized protocols, with longer follow-up and prespecified endpoints, including cardiovascular events and patient-centered outcomes. Such studies should incorporate rigorous methods to measure adherence, use ambulatory blood pressure monitoring, and stratify by clinical subgroups (for example, CAD, heart failure, sex, and age). Cost-effectiveness analyses would help determine whether HGT provides incremental value over standard care, given device costs and personnel requirements.

Conclusion

In this retrospective cohort, hemodynamics-guided therapy using individualized hemodynamic profiles among patients with coronary artery diseases and other cardiovascular comorbidities was associated with greater reductions in systolic and diastolic blood pressure compared with standard care. These associations are biologically plausible and generally concordant with prior, smaller studies; however, causal inference cannot be established given the nonrandomized design of this study. Prospective randomized trials with standardized protocols, longer follow-up, rigorous assessment of treatment adherence, ambulatory blood pressure monitoring, and cost-effectiveness evaluations are needed to determine whether hemodynamics-guided therapy provides sustained clinical benefit and should be incorporated into routine clinical practice.

Data Sharing Statement

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethics Approval and Consent to Participate

This study was approved by the Institutional Review Board (IRB) of Chung Shan Medical Hospital (CS2-18089). Informed consent was obtained from all participants before data collection.

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, revising or critically reviewing 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.

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Disclosure

The authors declare that they have no conflicts of interest in this work.

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