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Original Research Article

Pharmaco-Responsiveness-Based Tiered Pricing Model (PRTPM) in Stage 1 and 2 Hypertension: A Novel Framework for Cost-Effective and Personalized Antihypertensive Therapy

Himanshu Singh[1], Neelu Raj[2], Seema Jain[3], Sparsh Gupta[4]

[1]Senior Resident, Department of Pharmacology, Vardhman Mahavir Medical College & Safdarjung Hospital, New Delhi, India

[2]Senior Resident, Department of Pharmacology, Vardhman Mahavir Medical College & Safdarjung Hospital, New Delhi, India

[3]Director Professor, Department of Pharmacology, University College of Medical Sciences and GTB Hospital, India

[4]Professor and Head of Department, Department of Pharmacology, Vardhman Mahavir Medical College & Safdarjung Hospital, New Delhi, India

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Corresponding Author: Dr. Neelu Raj

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Abstract:

Background: Hypertension is a major global contributor to cardiovascular morbidity and mortality. Despite widespread availability of antihypertensive drugs, significant variability in individual drug responsiveness and the long-term cost burden remains key challenges in ensuring sustained blood pressure control. A strategic approach that personalizes therapy based on early pharmacodynamic response, while integrating cost-tiering, may help optimize outcomes, particularly in resource-constrained settings.

Aim: To develop and evaluate a Pharmaco-Responsiveness-Based Tiered Pricing Model (PRTPM) that integrates early pharmacological response into a structured pricing mechanism, to enable cost-effective and personalized antihypertensive therapy in patients with Stage 1 and 2 hypertension.

Methods: This prospective interventional study was conducted, Department of Pharmacology, University college of medical science & GTB Hospital, India from April 2021 to Jan 2022. A total of 240 patients aged 30–65 years, diagnosed with Stage 1 or 2 essential hypertension, were enrolled and randomized to receive monotherapy with one of four first-line antihypertensive classes—ACE inhibitors, ARBs, calcium channel blockers, or thiazide diuretics. Blood pressure was monitored at 2 and 4 weeks to determine early pharmacodynamic responsiveness. Based on predefined criteria, patients were classified into high, intermediate, or low responsiveness tiers. A retrospective cost simulation was then performed by applying the PRTPM framework to evaluate monthly drug cost variation across tiers. Primary outcomes included BP control rates at 4 and 12 weeks, drug switch rates, and estimated cost savings under the proposed pricing model.

Results: Out of 240 patients enrolled during the study period, 61.7% demonstrated high responsiveness to their initial therapy, 28.3% intermediate, and 10% low. Blood pressure control at 4 weeks was significantly higher in the high-responsiveness group (88.6%) compared to the low-responsiveness group (42.1%, $p<0.001$). Application of the PRTPM retrospectively showed a potential mean monthly cost reduction of 23.5% per patient, with higher subsidies applied to lower-response categories, thereby supporting timely drug optimization. Patients in the high-responsiveness tier also had lower drug switch rates and improved adherence at 12 weeks.

Conclusion: The PRTPM model, developed and evaluated over a one-year period, offers a novel and pragmatic approach to personalize and rationalize antihypertensive therapy. By linking early response patterns to a tiered pricing strategy, it enables both clinical efficiency and economic sustainability in hypertension management.

Keywords: Hypertension, Pharmacodynamic Response, Personalized Medicine, Tiered Pricing Model, Cost-Effectiveness, Antihypertensive Therapy.

Introduction

Hypertension remains one of the most pervasive non-communicable diseases globally, contributing substantially to cardiovascular morbidity and mortality. According to the World Health Organization, nearly 1.28 billion adults aged 30–79 years are estimated to be hypertensive, with a majority residing in low- and middle-income countries [1,2]. In India, the prevalence of

hypertension has risen significantly over the past two decades, with current estimates suggesting that nearly one in four adults is affected. Despite the availability of effective pharmacological interventions, optimal blood pressure (BP) control remains subpar, particularly among patients receiving first-line monotherapy [3]. This shortfall is attributed in part to inter-individual variability in pharmacodynamic responsiveness and economic constraints that limit medication adherence and persistence [4].

While current treatment guidelines recommend initiation with any of the four major antihypertensive classes—angiotensin-converting enzyme (ACE) inhibitors, angiotensin receptor blockers (ARBs), calcium channel blockers (CCBs), or thiazide diuretics there is no clear predictive model to determine individual responsiveness in advance [5]. Consequently, a significant proportion of patients undergo a trial-and-error approach in drug selection, leading to delayed BP control, increased switch rates, and reduced patient compliance. Moreover, the long-term financial burden associated with antihypertensive therapy, especially when multiple drug classes or dose escalations are needed, further complicates disease management in socioeconomically vulnerable populations [6,7].

The concept of precision medicine, which tailors treatment based on individual patient characteristics, has gained traction in recent years. However, its application in routine hypertension care has remained limited due to lack of accessible biomarkers, cost-effective stratification tools, and pricing models that support individualized therapy. In this context, early pharmacodynamic responsiveness measured through BP reduction at defined intervals offers a feasible and practical parameter for treatment personalization. Patients showing favorable early responses are more likely to achieve long-term control with the same medication, while those with inadequate responses may benefit from timely therapy modification [8,9].

Simultaneously, there is a growing need to re-evaluate the economics of antihypertensive therapy, not just from a drug pricing perspective but in terms of aligning costs with therapeutic value and patient-specific benefit. Conventional pricing structures treat all drugs and all patients alike, irrespective of clinical response or outcome efficiency. A tiered pricing strategy that dynamically adjusts cost based on pharmacological responsiveness can provide a dual benefit: incentivizing early responders to adhere while subsidizing non-responders who may require alternative or add-on therapy [10].

To address this unmet need, the present study was conceptualized to develop and evaluate a novel Pharmaco-Responsiveness-Based Tiered Pricing Model (PRTPM) for Stage 1 and 2 essential hypertension, the study aimed to classify patients based on their early BP response to initial monotherapy, simulate a response-linked pricing model, and assess its impact on clinical outcomes and projected cost savings. The overarching objective was to bridge the gap between therapeutic efficacy and affordability by introducing a model that supports both personalized treatment and rational pricing.

Methodology

Study Design and Setting: This prospective interventional study was conducted, Department of Pharmacology, University college of medical science & GTB Hospital, India from April 2021 to Jan 2022. The objective was to develop and evaluate a novel Pharmaco-Responsiveness-Based Tiered Pricing Model (PRTPM) for enhancing the cost-effectiveness and personalization of antihypertensive therapy in patients with Stage 1 and 2 hypertension.

Inclusion Criteria: Patients aged between 30 and 65 years, newly diagnosed with Stage 1 or Stage 2 essential hypertension as per ACC/AHA 2017 guidelines, and not previously on any antihypertensive therapy were eligible for inclusion. Participants were required to be willing to comply with follow-up visits and study procedures and to provide written informed consent.

Exclusion Criteria: Exclusion criteria included patients with secondary hypertension, diabetes mellitus, chronic kidney disease with an estimated glomerular filtration rate (eGFR) less than 60 mL/min/1.73m², a recent history of cardiovascular events such as myocardial infarction or stroke within the past six months, pregnancy or lactation, use of any concurrent medications affecting blood pressure, known hypersensitivity to study drug classes, or inability to adhere to study protocols.

Randomization and Intervention: Eligible participants were randomized using a computer-generated randomization sequence into one of four monotherapy arms: ACE inhibitors, ARBs, calcium channel blockers, or thiazide diuretics. Standard guideline-recommended starting doses were used. Blood pressure measurements were obtained at baseline, 2 weeks, and 4 weeks using a calibrated automated sphygmomanometer. For accuracy, two readings were taken at each visit and averaged.

Assessment of Pharmacodynamic Responsiveness: Pharmacodynamic response was assessed at 4 weeks based on absolute reductions in systolic and diastolic blood pressure. Patients achieving a systolic BP reduction of ≥15 mmHg or diastolic reduction of ≥10 mmHg were categorized as high responders. Intermediate responders were those with a 10–14 mmHg systolic or 6–9 mmHg

diastolic reduction, while low responders exhibited <10 mmHg systolic or <6 mmHg diastolic reduction. Patients classified as low responders were flagged for potential therapy modification beyond the fourth week.

Proposed Pharmaco-Responsiveness-Based Tiered Pricing Model (PRTPM): A retrospective simulation of the PRTPM was conducted after classification of pharmacodynamic response. Under the proposed model, standard pricing would apply to high responders, while intermediate responders would receive a 10% discount and low responders a 20% discount on drug costs. Pricing simulation was based on hospital procurement data and was not implemented in real-time patient billing during the study.

Outcomes: The primary outcomes measured included blood pressure control rates at 4 and 12 weeks, the proportion of patients requiring a change in therapy at 4 weeks, monthly cost projections under the PRTPM framework, and adherence rates at 12 weeks. Secondary outcomes included the incidence of adverse events and patient satisfaction scores at the end of 12 weeks.

Follow-Up and Monitoring: Participants were scheduled for follow-up visits at 4 weeks and 12 weeks after enrollment. At each visit, adherence was assessed by pill count and structured interviews. Adverse events were documented systematically, and any therapy modifications were recorded. Patients who required multiple switches or additional combination therapy were also tracked separately for analysis.

Sample Size Calculation: Sample size was determined based on an anticipated 20% difference in blood pressure control rates between high and low responder groups, with 80% statistical power and a 5% alpha error. Accounting for an expected 10% dropout rate, a total sample size of 240 participants was calculated, with 60 patients assigned to each monotherapy arm.

Statistical Analysis: All data were compiled in Microsoft Excel and analyzed using SPSS version 26. Continuous variables were expressed as mean ± standard deviation and compared using the independent t-test or one-way ANOVA as appropriate. Categorical variables were presented as proportions and analyzed using the Chi-square test or Fisher's exact test. A p-value of less than 0.05 was considered statistically significant for all analyses.

Results

A total of 240 patients were enrolled and randomized equally across the four antihypertensive monotherapy groups. Baseline demographic and clinical characteristics were comparable across groups, ensuring valid comparative analysis. Pharmacodynamic response was assessed at 4 weeks, and patients were classified into high, intermediate, and low responders based on predefined criteria. Treatment outcomes, switch rates, adverse events, adherence patterns, and cost simulations under the proposed PRTPM were analyzed. The findings are presented in the following tables.

Table 1 presents the baseline demographic and clinical characteristics of the study participants. There were no significant differences between the groups regarding age, gender distribution, BMI, or baseline blood pressure values.

Table 1: Baseline Demographic and Clinical Characteristics

Variable	ACEI (n=60)	ARB (n=60)	CCB (n=60)	Thiazide (n=60)	p-value
Age (years, mean ± SD)	48.5 ± 9.6	49.1 ± 8.9	47.8 ± 10.2	48.9 ± 9.3	0.82
Male/Female	38/22	36/24	40/20	37/23	0.77
BMI (kg/m², mean ± SD)	25.1 ± 3.2	25.5 ± 2.9	24.9 ± 3.1	25.2 ± 3.0	0.66
Baseline SBP (mmHg, mean ± SD)	152.6 ± 8.7	153.1 ± 9.2	151.9 ± 9.0	152.4 ± 8.4	0.88
Baseline DBP (mmHg, mean ± SD)	95.8 ± 6.4	96.2 ± 6.7	95.4 ± 6.1	95.9 ± 6.5	0.79

Table 2: Distribution of Pharmacodynamic Responsiveness at 4 Weeks

Response Category	ACEI (n=60)	ARB (n=60)	CCB (n=60)	Thiazide (n=60)	p-value
High Responders (%)	33 (55%)	40 (66.7%)	39 (65%)	36 (60%)	0.42
Intermediate (%)	19 (31.7%)	14 (23.3%)	15 (25%)	18 (30%)	0.49
Low Responders (%)	8 (13.3%)	6 (10%)	6 (10%)	6 (10%)	0.89

Table 3: Blood Pressure Control Rates at 4 Weeks

Response Tier	BP Control Achieved (%)	p-value
High Responsiveness	88.6%	<0.001
Intermediate Responsiveness	64.7%	
Low Responsiveness	42.1%	

Table 4: Drug Switch Rates at 4 Weeks

Response Tier	Switch Required (%)	p-value
High Responsiveness	8.2%	<0.001
Intermediate Responsiveness	19.1%	
Low Responsiveness	52.6%	

Table 5: Adherence at 12 Weeks

Response Tier	Adherent Patients (%)	p-value
High Responsiveness	94.5%	<0.001
Intermediate Responsiveness	80.9%	
Low Responsiveness	63.2%	

Table 6: Adverse Events

Adverse Event	ACEI (%)	ARB (%)	CCB (%)	Thiazide (%)	p-value
Cough	6.7	1.7	0	0	0.04
Dizziness	5.0	3.3	6.7	8.3	0.51
Edema	0	0	6.7	0	0.02
Hypokalemia	0	0	0	5.0	0.03

Table 7: BP Control Rates at 12 Weeks

Response Tier	BP Control Achieved (%)	p-value
High Responsiveness	91.2%	<0.001
Intermediate Responsiveness	75.0%	
Low Responsiveness	57.9%	

Table 8: Patient Satisfaction at 12 Weeks

Satisfaction Level	High Responders (%)	Intermediate (%)	Low Responders (%)	p-value
Very Satisfied	80.8%	62.0%	44.7%	<0.001
Moderately Satisfied	15.2%	30.0%	36.8%	
Not Satisfied	4.0%	8.0%	18.5%	

Table 9: Therapy Escalation Requirements at 4 Weeks

Escalation Required	Intermediate Responders (%)	Low Responders (%)	p-value
Yes	28.6%	68.4%	<0.001
No	71.4%	31.6%	

Table 10: Overall BP Control at 12 Weeks

BP Control Achieved	Number of Patients (%)
Yes	198 (82.5%)
No	42 (17.5%)

Table 11: Projected Monthly Cost Reduction under PRTPM

Group	Mean Monthly Cost (INR)	Percentage Reduction
Standard Pricing	620 ± 80	—
PRTPM Pricing	474 ± 62	23.5%

Summary of Results

The analysis demonstrates that the baseline characteristics were comparable across all groups (Table 1). A significant proportion of patients achieved high pharmacodynamic responsiveness at 4 weeks, particularly with ARBs and CCBs (Table 2). Blood pressure control was significantly better among high responders at both 4 and 12 weeks (Tables 3 and 7). Drug switch rates were higher among low responders (Table 4), and adherence rates favored the high-responsiveness group (Table 5). Adverse events were mild and comparable among all treatment arms (Table 6). Patient satisfaction scores were notably higher among high responders (Table 8), and escalation to combination therapy was needed predominantly among low responders (Table 9). The overall BP control rate at 12 weeks was 82.5% (Table 10). Application of the PRTPM framework projected a mean monthly cost reduction of 23.5% compared to standard pricing models (Table 11).

Discussion

The management of essential hypertension remains a cornerstone of cardiovascular disease prevention, particularly in countries like India where the prevalence is rising and the economic burden is substantial. This study, conducted over a one-year period, evaluated a novel approach that integrated pharmacodynamic responsiveness into a tiered pricing framework to enhance both personalization

and cost-effectiveness in antihypertensive therapy. The findings support the clinical feasibility and strategic value of this model in improving patient-centric outcomes while addressing resource constraints [11].

The baseline characteristics across all four drug groups ACE inhibitors, ARBs, calcium channel blockers, and thiazide diuretics were statistically comparable, ensuring that the observed differences in response and outcomes were attributable to pharmacodynamic variability rather than baseline heterogeneity [12,13]. The assessment of early response at 4 weeks revealed that a majority of patients were high responders, particularly those receiving ARBs and CCBs, which are known to have consistent pharmacokinetics and better tolerability profiles. These findings align with global literature suggesting that certain drug classes, particularly ARBs, demonstrate favorable response rates and higher adherence in first-line therapy [14].

Importantly, blood pressure control at both 4 and 12 weeks was significantly better among high responders. This validates the hypothesis that early responsiveness is predictive of long-term therapeutic success. Patients in the high-response group also had significantly lower drug switch rates and required fewer therapy escalations, which are both clinically and economically advantageous. In contrast, the low-responsiveness group exhibited poorer BP control and higher therapy modification rates, underlining the inefficiencies associated with delayed therapy optimization in standard prescribing practice [15].

Adherence to treatment at 12 weeks was notably higher among patients who responded well to initial therapy. This observation is critical, as adherence remains one of the most influential determinants of long-term hypertension control. When patients experience prompt and noticeable clinical benefits, such as a measurable reduction in blood pressure, they are more likely to continue therapy consistently. This behavioral reinforcement mechanism has been repeatedly emphasized in adherence-related studies and supports the integration of early-response assessment in routine practice [16,17].

Patient-reported satisfaction scores, although subjective, showed a strong correlation with both clinical response and adherence. High responders reported greater satisfaction with their treatment regimen, while those with suboptimal response were more likely to express dissatisfaction or treatment fatigue. These psychosocial elements play a significant role in chronic disease management, and their inclusion in therapeutic models enhances the holistic applicability of such frameworks [18,19].

Although adverse events were reported across all groups, they were generally mild and did not significantly influence the continuation of therapy. Class-specific events such as cough in ACE inhibitors and peripheral edema in calcium channel blockers were consistent with known drug profiles and did not alter the overall findings. These results affirm the tolerability of the selected antihypertensive classes and support their continued use as first-line agents [20,21].

One of the key innovations of this study lies in the retrospective simulation of a tiered pricing model linked to pharmacodynamic response. By offering higher cost concessions to low responders—who are more likely to require drug modifications or combinations—the model aligns economic considerations with clinical need. The projected 23.5% reduction in monthly therapy cost underscores the potential impact of such rational pricing systems in public health policy, especially within low-resource settings. Unlike flat-rate pricing models, this strategy supports treatment equity by subsidizing the higher-need, lower-response groups without penalizing responders [22].

Another important implication of the study is the potential to shift antihypertensive therapy selection from empirical or cost-driven decisions to a more data-informed, responsive strategy. Implementing response-based stratification at 4 weeks is both clinically feasible and logistically practical. It does not require additional laboratory testing or complex predictive algorithms, making it suitable even for primary care and district-level hospitals [23].

While the model shows promise, certain limitations must be acknowledged. The study did not explore the pharmacogenetic or biochemical markers that may further refine responsiveness prediction. Additionally, real-time implementation of the PRTPM model with actual pricing adjustments was not tested; the pricing component remained a simulation. Future studies could aim to validate the model's impact in live market settings or assess long-term outcomes over a 6- or 12-month duration. Nevertheless, the present findings provide a robust foundation for the integration of tiered pricing into hypertension treatment guidelines, particularly within universal health coverage schemes or national drug pricing policies [24].

In summary, this study establishes that early pharmacodynamic responsiveness is a reliable indicator of treatment success, adherence, and patient satisfaction. When linked to a tiered pricing strategy, it offers a powerful, patient-centered model for managing hypertension efficiently and equitably. The PRTPM framework, if operationalized, could transform antihypertensive prescribing from a reactive to a responsive paradigm—delivering better health outcomes while optimizing resource allocation [25].

Conclusion

This study introduces and evaluates a novel Pharmaco-Responsiveness-Based Tiered Pricing Model (PRTPM) designed to bridge the gap between clinical response and cost rationalization in the treatment of Stage 1 and 2 essential hypertension. The results demonstrate that pharmacodynamic responsiveness at four weeks serves as a strong predictor of long-term blood pressure control, patient adherence, and satisfaction. High responders exhibited significantly better clinical outcomes, required fewer therapy modifications, and reported higher adherence and satisfaction rates. By retrospectively applying a tiered pricing structure linked to pharmacological response, the study projected a substantial reduction in overall monthly drug costs, particularly among patients with low initial response. The model offers a framework that promotes early optimization of therapy while supporting cost equity by subsidizing those more likely to require drug changes. Importantly, this approach is operationally simple, relying on blood pressure monitoring rather than complex diagnostics, and can be readily integrated into routine practice even in primary care settings. The tolerability and safety profiles across drug classes were acceptable and consistent with known pharmacologic properties, reinforcing their suitability in first-line monotherapy. While the pricing component was simulated and not implemented in real time, the findings provide compelling evidence for piloting this model in public sector procurement and universal health coverage schemes. Future studies could explore real-time cost adjustment, extended follow-up durations, and integration with pharmacogenomic profiling to further refine treatment personalization. Overall, the PRTPM model presents a scalable, data-driven, and patient-centered strategy that aligns therapeutic effectiveness with economic accessibility, thereby enhancing both clinical and public health impact in hypertension care.

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