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Effects of medication procurement reforms and extended prescription duration on medication coverage for hypertension in India's public health system: a modelling study

Matti Marklund ,[1,2,3,4] T Joseph Mattingly II ,[5] Swagata Kumar Sahoo,[6] Prabhdeep Kaur ,[7] Andrew E Moran,[6,8] Lawrence J Appel,[2,9,10] Kunihiro Matsushita[2,9]

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For numbered affiliations see end of article.

Correspondence to
Dr Matti Marklund;
mmarklu1@jhu.edu

ABSTRACT

Objectives To estimate the effects of procurement reforms and extended prescription duration on medication coverage for hypertension in India's public health system.

Design Simulation study incorporating data from governmental medication price lists, prescription pattern analyses, and market sales surveys.

Setting Simulated hypothetical public healthcare facility in India treating 1000 patients with hypertension.

Participants Patients with medication-treated hypertension.

Interventions (1) Focused procurement by reducing antihypertensive medication classes from 5 to 3 and selecting one medication within class; (2) Increased use of single-pill combinations (SPC) and (3) Only SPC dispensation. The base scenario consisted of procurement of multiple medications across classes, 1-month prescription duration and no use of SPC. We repeated all scenarios with extended prescription duration (3 months vs 1 month).

Main outcome measures Medication coverage is defined as the maximum number of patients with adequate medication without exceeding the base scenario budget.

Results With 1-month prescriptions, focused procurement alone was estimated to increase medication coverage by 17.8% (95% uncertainty interval: 16.2%; 19.6%) compared with the base scenario. Medication coverage improved by 3.6% (2.8%; 4.4%) with increased SPC use and by 10.3% (8.3%; 12.3%) with only SPC dispensation. Combining focused procurement and increased SPC use increased medication coverage by 20.2% (18.3%; 22.1%). When the prescription duration was extended to 3 months, the medication coverage was further increased by ~40% (eg, net improvement of ~60% with focused procurement, increased SPC use and 3-month prescriptions vs the base scenario).

Conclusions With a fixed budget for medication procurement and dispensation, the combination of focused procurement, increased SPC use and extended prescription periods could substantially increase the number of patients who receive hypertension medications in India's public health system. Our study highlights the benefits of implementing these reforms to scale up medication coverage for hypertension in India and potentially elsewhere.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Over 200 million individuals in India have hypertension but only 15% of those are treated, partly due to limitations in the medication supply. Reforms to increase medication coverage are crucial to improve blood pressure control.

WHAT THIS STUDY ADDS

⇒ By focusing procurement on fewer antihypertensive medications, increasing the use of single-pill combinations and extending the prescription period to 3 months, the number of patients receiving medication could increase by up to 60%, without increasing the budget for medication procurement and dispensation.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Together with other reforms in the public health system, these three reforms of medication procurement and dispensation could substantially increase medication coverage for hypertension in India.

INTRODUCTION

Hypertension is the leading risk factor for mortality, accounting for one in five deaths worldwide.[1] In 2019, about 1.3 billion adults aged 30–79 years were estimated to have hypertension, but less than half of them were under treatment, and only 20% had their blood pressure under control.[2] The burden of hypertension is especially high in low-income and middle-income countries

(LMICs),[1] where insufficient and irregular medication supply has been a major barrier to increasing hypertension treatment.[3]

India is not an exception, with the prevalence of hypertension of 25% (~207 million adults), roughly equivalent to 20% of all individuals with hypertension in the world.[4] In India, 28% of patients with hypertension are aware of hypertension, and only 15% are being treated.[5] To improve this dismal situation, the Government of India initiated in 2010 a national programme to screen and manage hypertension and has worked with multiple organisations through the India Hypertension Control Initiative (IHCI), formed in 2017.[6] By following the WHO HEARTS approach,[7] IHCI aims to strengthen the Government of India's management of hypertension by building competencies of health professionals and ensuring the pharmaceutical supply chain at district and healthcare facility levels.

Two of the five crucial components of IHCI focus on implementing a standardised treatment protocol with 2–3 classes of medications and improving the availability of the recommended protocol drugs. Single-pill combination (SPC) products, where two or more antihypertensive agents are combined in one pill, have been recommended by the WHO[8] and could potential be key in achieving these goals. Compared with multiple single-agent pills, SPCs have several advantages, including synergistic biological effects from combined classes, lower risk of side effects, improved adherence, simplified supply chain and lower price via economy of scale.[8] However, SPCs are still uncommon for hypertension care in India, with only a few states procuring these medications.[9]

The frequency of medication refills is another critical barrier in LMICs. Frequent refills, often required monthly or even more frequently, can result in reduced adherence due to increased costs, travel and visit time, and administrative burden. During the COVID-19 pandemic, multimonth prescriptions were implemented in three states participating in IHCI (Madhya Pradesh, Maharashtra and Punjab), which reduces the frequency of medication dispensation.[10]

These reforms address key structural barriers to hypertension care, including fragmented procurement systems, limited availability of medications and burdensome refill schedules, which are common challenges in resource-limited healthcare systems.

To the best of our knowledge, no previous studies have quantified to what extent these medication procurement and prescription reforms could improve medication coverage for hypertension. Such analyses are essential to guide evidence-based policy reforms in India and other LMICs. Therefore, we estimated the individual and combined effects of medication procurement reforms and extended prescription duration on medication coverage for hypertension in India's public healthcare system.

METHODS

We developed and used a new modelling framework for this study (figure 1) to simulate hypertension medication dispensation and related costs for a typical government-owned clinic in India. By government-owned clinic, we are referring to public sector clinics that provide clinical services including dispensing medications to patients with no out-of-pocket charge. Because no existing framework was identified that could address the specific features of this study (eg, capturing state-level variability in procurement prices and the logistics of dispensing SPCs), we designed a simulation model tailored to these complexities. The model accounts for the unique characteristics of India's public health procurement system and allows us to simulate multiple reform scenarios. The modelling framework allowed us to compare multiple reforms, either individually or in combination, within the constraints of a fixed budget typical for such clinics.

The model simulated a population of 1000 hypertensive patients, each assigned to 1 of 12 common antihypertensive regimens based on real-world prescription patterns in India. We estimated medication costs using public procurement prices from nine Indian states and calculated total costs for both procurement and dispensation. We assumed that medication procurement prices could be reduced if larger quantities of the medication were procured but that the magnitude of the reduction would be dependent on the baseline price. Additionally, we assumed a reduction in dispensation costs if fewer types of medications were procured and stored, to reflect efficiency gains due to faster product selection and reduced time spent on inventory tasks, such as procurement and restocking. The total budget was set based on the base scenario of providing a 1-month prescription to all 1000 patients. The difference in outcomes between the base scenario and the intervention scenarios (which included reforms such as focused procurement, increased use of SPCs and extended prescription durations) was calculated in terms of the maximum number of patients who could be covered without exceeding the fixed budget. Key inputs and assumptions are described in table 1.

Medication cost and budget estimation

We generated a clinic population consisting of 1000 patients receiving antihypertensive medications, typical groups of patients with medication-treated hypertension (figure 1). Each of the generated patients was assigned to 1 of 12 commonly prescribed antihypertensive medication regimens in India, with probabilities for being assigned to each medication regimen informed by reported prescription patterns of five classes of antihypertensive medications in India, including ACE inhibitors (ACE-I), angiotensin II receptor blockers (ARB), beta-blockers (BB), calcium channel blockers (CCB) and thiazide diuretics (TD) (online supplemental table 1).[11 12] Given the lack of published data on within-class medication prevalence in the public health system, one author with experience in public procurement of antihypertensive medications

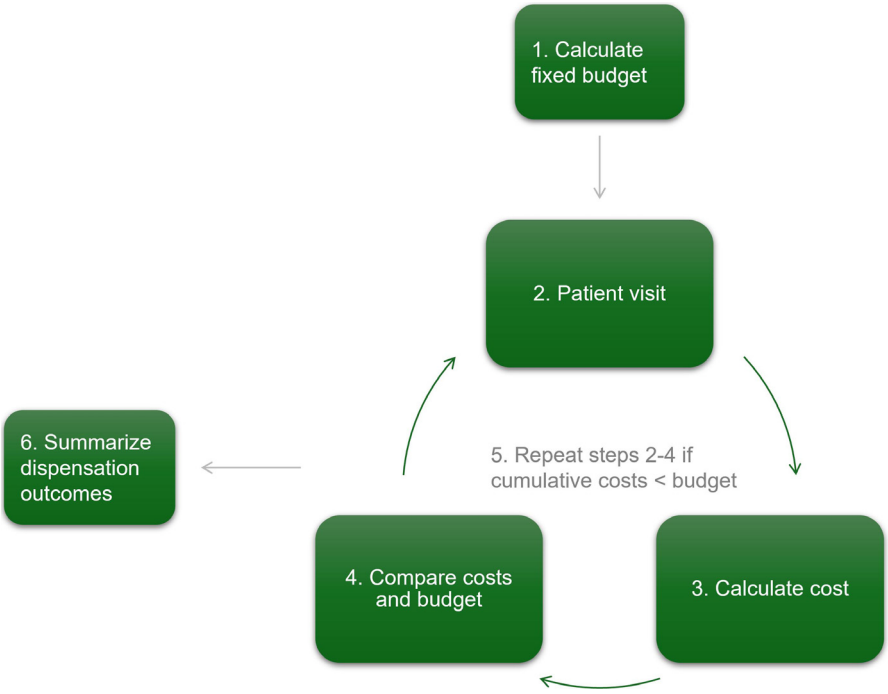

Figure 1 Schematic representation of the simulation framework used. First, a population of (n=1000) patients is generated, each with certain antihypertension medication requirements which are informed by current medication patterns in Indian healthcare facilities. The medication requirement for each patient is estimated and a fixed budget is calculated as the sum of costs for procurement and dispensation of all prescribed antihypertension medications for the 1000 patients (1). Patient *i* with a specific prescription of antihypertensive medication visits the clinic (2). The cost associated to procuring and dispensing medication to patient *i* is calculated, as well as the cumulative cost associated with patient *i* and all previous patients (**3**). The cumulative cost is compared with the fixed budget and if the cumulative costs are less than the budget, patient *i* receives the medication, and the procedure is repeated for patient *i+1* (**4–5**). If the cumulative cost exceeds the budget when patient *j* visits the clinic, the simulation is terminated, patient *j* leaves without medication, and the following dispensation outcomes are summarised: patients with sufficient medication, pill dispensed and costs (total, medication and dispensation) (6).

in India (SKS) provided estimates of within-class proportions (online supplemental table 2).

The cost for each medication regimen was derived from reported procurement prices of the public health systems in nine states (ie, Rajasthan, Madya Pradesh, Uttar Pradesh, Telangana, Kerala, Gujrat, Odisha, Tamilnadu and Chhattisgarh) (online supplemental table 3).[9] In the primary analysis, the procurement price of each medication was determined as the mean procurement price across the states with available price information for that medication (online supplemental tables 2–3). To reflect the potential impact of price heterogeneity, we conducted sensitivity analyses using the minimum and maximum procurement prices observed among the nine states. This approach allowed us to explore how variations in state-level procurement efficiencies and costs might influence medication coverage outcomes under the reform scenarios. Details on how medication prices were derived are given in the online supplemental appendix, while medication prices assumed in the different scenarios are presented in online supplemental table 2, and summary information on reported medication prices across different states and under the Jan-Aushadi scheme can be found in online supplemental table 3.

The total budget in the base scenario was calculated as the sum of the cost for procuring and dispensing medication to the generated patient population (n=1000):

$$c = nd + \sum_{i=1}^{n} r_i \quad (1)$$

where c is the total budget, n is the patient population size (ie, n=1000), d is the dispensation cost per patient, r_i is the medication cost for patient i. The medication cost per patient (r_i) was calculated as:

$$r_i = \sum_{j=i}^{m_i} k_{ij} \cdot p_j \cdot q_i \quad (2)$$

where m_i is the total number of medication types prescribed to patient i, k_{ij} is the number of pills per day of medication j prescribed to patient i, p_j is the price per pill for medication j and q_i is the prescription duration in days for patient i.

Scenarios

In this study, we compared a base scenario with intervention scenarios, each comprising one or more procurement reforms (ie, focused medication procurement, increased SPC use and only SPC dispensation) and/or extended prescription duration of 2 or 3 months (table 2). In the

Table 1 Key input data and assumptions

Input	Stratification	Values	Source	Note
Prescripition patterns of antihypertensive medications	None	Online supplemental table 1	RTSL/IQVIA fact sheet and Narkar *et al*.[11] (Biomed Pharmacol J, 2021)	Based on data from the RTSL/IQVIA on prescription patterns in the private sector and data from Narkar *et al* presenting prescription patterns (n=200 patients) collected January–December 2019 in a tertiary care hospital in Maharashtra, we defined the most common antihypertensive medication regimens (ie, assumed to be prescribed to ≥1% of all patients with hypertension).
Base case procurement prices of antihypertensive medication	None	Online supplemental table 2	Drugs and Vaccine Delivery Management System, Central Dashboard, Ministry of Health and Family Welfare, Govt. of India.*	In the primary analysis, the baseline procurement price of each medicine was determined as the mean procurement price reported by n≤9 states (ie, Rajasthan, Madya Pradesh, Uttar Pradesh, Telangana, Kerala, Gujrat, Odisha, Tamilnadu and Chhattisgarh).
Reform effects on prescription patterns	Reform	Table 2, online supplemental tables 1 and 3	Authors' assumptions	We assumed that in scenarios with focused procurement ACE-I would be replace by ARB, while BB would be replaced by CCB. The regimen with BB and CCB was assumed to be replaced by ARB and CCB. Increased use of SPC was not assumed to influence medication regimens, while in the scenarios with only SPC prescribed we assumed similar replacements for BB and CCB as for focused procurement and furthermore, we assumed that patients currently on monotherapeutic regimens (ie, 1 pill per day) would replace those with SPCs (0.5 pill per day).
Reform effects on procurement prices	Reform and medication	Online supplemental table 2	Authors' assumptions	By targeting procurement to fewer medications within classes, we assumed that the prices for targeted medications would be additionally discounted, with the additional discount being dependent on the current level of discount (appendix).
Dispensation costs	Reform	Table 2	Abdulsalim *et al*[14] and Karia *et al*[13]	Based on data from Abdulsalim *et al* and Karia *et al*, we defined the cost of dispensation as 8.5 rupees per occasion in the current practice and increased SPC use scenarios, and 6.5 rupees per occasion for the other scenarios (table 2).†

*Accessed on May 20 2023 from https://cdashboard.dcservices.in/CDDB/hissso/loginLoginV3.cwh (restricted access).
†The method to derive cost per dispensation (rupees/patient) is described in appendix.
ARBs, angiotensin II receptor blockers; BB, beta blocker; CCB, calcium channel blocker; SPC, single-pill combination.

Table 2 Summary of simulated scenarios

Scenario	Prescription period, months	Medication regimens, n	Use of SPC	Medications available for procurement		
				Medication classes, n	Individual medications, n	Cost per dispensation (rupees/patient)*
(1) Current procurement, no SPC used (base scenario)	1	12	Not allowed	5 (calcium channel blocker, angiotensin II receptor blocker, ACE inhibitor, beta blocker, thiazide)	11 (amlodipine, nifedipine, telmisartan, losartan, olmesartan, ramipril, enalapril, metoprolol succinate, atenolol, hydrochlorothiazide, chlorthalidone)	8.5
(2) Focused procurement	1	6	Not allowed	3 (calcium channel blocker, angiotensin II receptor blocker, thiazide)	7 (amlodipine, losartan, hydrochlorothiazide)	6.5
(3) Increased SPC use	1	12	Allowed for eligible patients†	5 (calcium channel blocker, angiotensin II receptor blocker, ACE inhibitor, beta blocker, thiazide)	13 (amlodipine, nifedipine, telmisartan, losartan, olmesartan, ramipril, enalapril, metoprolol succinate, atenolol, hydrochlorothiazide, chlorthalidone, losartan/hydrochlorothiazide, amlodipine/telmisartan)	8.5
(4) Only SPC dispensed	1	6	Dispensed to all patients	3 (calcium channel blocker, angiotensin II receptor blocker, thiazide)	2 (losartan/hydrochlorothiazide, amlodipine/telmisartan)	6.5
(5) Increased SPC use+focused procurement	1	6	Allowed for eligible patients	3 (calcium channel blocker, angiotensin II receptor blocker, thiazide)	5 (amlodipine, losartan, hydrochlorothiazide, losartan/hydrochlorothiazide, amlodipine/telmisartan)	6.5
(6) Current procurement, no SPC used	3	12	Not allowed	5 (calcium channel blocker, angiotensin II receptor blocker, ACE inhibitor, beta blocker, thiazide)	11 (amlodipine, nifedipine, telmisartan, losartan, olmesartan, ramipril, enalapril, metoprolol succinate, atenolol, hydrochlorothiazide, chlorthalidone)	8.5
(7) Focused procurement	3	6	Not allowed	3 (calcium channel blocker, angiotensin II receptor blocker, thiazide)	7 (amlodipine, losartan, hydrochlorothiazide)	6.5
(8) Increased SPC use	3	12	Allowed for eligible patients†	5 (calcium channel blocker, angiotensin II receptor blocker, ACE inhibitor, beta blocker, thiazide)	13 (amlodipine, nifedipine, telmisartan, losartan, olmesartan, ramipril, enalapril, metoprolol succinate, atenolol, hydrochlorothiazide, chlorthalidone, losartan/hydrochlorothiazide, amlodipine/telmisartan)	8.5
(9) Only SPC dispensed	3	6	Dispensed to all patients	3 (calcium channel blocker, angiotensin II receptor blocker, thiazide)	2 (losartan/hydrochlorothiazide, amlodipine/telmisartan)	6.5
(10) Increased SPC use+focused procurement	3	6	Allowed for eligible patients	3 (calcium channel blocker, angiotensin II receptor blocker, thiazide)	5 (amlodipine, losartan, hydrochlorothiazide, losartan/hydrochlorothiazide, amlodipine/telmisartan)	6.5

*The method to derive cost per dispensation (rupees/patient) is described in the online supplemental appendix.
†Patients with regimens that could be fully or partially replaced by one of two SPC: losartan/hydrochlorothiazide and telmisartan/amlodipine.
SPC, single-pill combination.

base scenario, we assumed that no SPCs were procured or dispensed, but all monotherapeutic pills from each of the five included classes were available for dispensation to patients for a prescription duration of 1 month, with no alterations from baseline medication prices (table 2). The cost of dispensation was assumed to 8.5 rupees per occasion using the estimated time to dispense a single prescription and pharmacy labour costs in India.[13 14]

In focused procurement, the number of medication classes was reduced from n=5 to n=3 by excluding ACE-I and BB from procurement and dispensation (table 2). Patients on ACE-I or BB were provided alternative medications (online supplemental table 1). In focused procurement, we assumed that the prices for targeted medications could be reduced compared with the base scenario prices, due to quantity discounts (online supplemental appendix and table 1). The degree of the additional discounts was defined based on the level of existing discount defined as the ratio of the average reported procurement price in up to nine states and the retail prices under the Jan-Aushadhi scheme of Government of India, launched by the Department of Pharmaceuticals to provide quality medicines at affordable prices (online supplemental appendix). We also assumed reduced costs of dispensation (ie, 6.5 rupees per occasion) to account for efficiency gains due to faster product selection and reduced time spent on inventory tasks such as procurement and restocking, as a result of focused procurement (table 2).[13 14]

For increased SPC use, replacement of multiple pills with SPC was allowed whenever possible and SPC alternative was available and at the same price or lower than the multipill alternative (table 2). We considered two SPCs currently procured by Indian states: losartan/hydrochlorothiazide and telmisartan/amlodipine. While some states also procure telmisartan/hydrochlorothiazide, the price of losartan/hydrochlorothiazide is usually lower (average price per pill: 0.59 vs 0.65 rupees),[9] and thus losartan/hydrochlorothiazide was included as the only SPC with ARB and TD. We assumed the same dispensation cost as in the base scenario.

In only SPC dispensation, we assumed that all patients were dispensed one of the two SPC described above (table 2 and online supplemental table 4). Patients who were on monotherapuetic regimens (ie, ACE-I, ARB, BB, CCB or TD) in the base scenario were dispensed one SPC with dosage 0.5 pills per day (online supplemental table 4).[15] Given that only SPC would be procured, with increased procurement volumes driving down prices, we assumed that the prices of SPC would be discounted compared with the baseline prices (online supplemental table 2). With only two SPCs dispensed (ie, losartan/hydrochlorothiazide and telmisartan/amlodipine), we assumed the same reduced dispensation costs as in focused procurement (table 2).

When increased SPC use and focused procurement were combined, SPCs were allowed and preferred for dispensation to eligible patients (ie, patients on multiple pills with separate agents) if the SPC alternative was cheaper than the corresponding alternative with multiple pills. As in focused procurement, ACE-I and BB were excluded. Thus, the alternative regimens only included ARB, CCB, and TD, or SPC thereof. Furthermore, only one single medication within each class was procured, and therefore, we assumed that the prices of the selected medications would be discounted due to larger anticipated procurement volumes (online supplemental table 2). Similarly, we assumed lower dispensation costs (ie, 6.5 rupees per occasion) due to the reduced number of medications procured and dispensed (table 2).

Simulation of medication procurement and dispensation

In all scenarios, we estimated the maximum number of patients that could be dispensed a sufficient supply of medication to cover their prescription, without exceeding the budget of the base scenario, that is, procuring and dispensing 1-month prescriptions of antihypertensive medication for 1000 patients. The cost (c_i) associated with each patient was calculated as:

$$c_i = d + \sum_{j=1}^{m_i} k_{ij} \cdot p_j \cdot q_i \quad (3)$$

where, d is the dispensation cost per patient, m_i is the total number of medication types prescribed to patient i, k_{ij} is the number of pills per day of medication j prescribed to patient i, p_j is the price per pill for medication j, and q_i is the prescription duration in days for patient i.

The maximum number of patients with sufficient mediation was determined as the maximum number of patients whose cumulative medication and dispensation costs did not exceed the budget of the base scenario (figure 1). The increase in medication coverage (defined as the maximum number of patients that could be under treatment with sufficient medication) was expressed as a percentage compared with the base scenario. All analyses were conducted in RStudio V.2023.06.0 (build 421).

Uncertainty and sensitivity analysis

The parameter uncertainty around the modelled estimates was quantified using Monte Carlo simulations (n=1000), where a random patient population with a specific order and prescription pattern was generated for each model iteration. The point estimate and 95% uncertainty intervals (UI) were defined as the mean and 2.5th–97.5th percentiles, respectively, of the distribution of the model outputs estimated across all 1000 iterations.

One-way deterministic sensitivity analyses were conducted to assess the robustness of simulation estimates to alternating input parameters (online supplemental table 5). We evaluated the impact of 20% higher or lower dispensation costs, as well as equal dispensation costs (ie, 8.5 rupees) in all scenarios. Furthermore, we evaluated the impact of higher and lower procurement prices, defined as the highest and lowest, respectively, procurement prices for up to nine states (online supplemental appendix 1).

RESULTS

The total budget (including costs for medication and dispensation) to ensure monthly supplies of antihypertensive medication prescribed for 1000 patients with common medication regimens in India (online supplemental table 1) was estimated to 20 213 rupees (95% UI: 19 760 ; 20 624), of which 11 713 rupees (11 260 ; 12 143) would be medication costs and the rest being costs for dispensing the medication (online supplemental figure 1).

Individual procurement reforms

Focused procurement

Compared with the base scenario, focused procurement could increase the medication coverage by 17.8% (95% UI 16.2%; 19.6%) without exceeding the budget (figure 2 and online supplemental figure 2). The total cost per patient a day was estimated to 0.57 (0.56; 0.58) rupees (figure 3), a reduction compared with the base scenario (0.67 (95% UI: 0.66; 0.69) rupees per patient and day) due to both lower medication costs (0.36 vs 0.39 rupees per patient and day) and dispensation costs (0.22 vs 0.28 rupees per patient a day). A total of 49 700 (48 500; 50 800) pills (all monotherapeutic) could be dispensed compared with 42 200 (41 200; 43 200) in the base scenario (online supplemental table 6).

Increased SPC use

Increased SPC use could increase the medication coverage by 3.6% (2.8%; 4.4%) compared with the base scenario (figure 2 and online supplemental figure 2). The cost per patient a day was estimated at 0.65 (0.64; 0.66) rupees, of which 0.37 (0.35; 0.38) rupees would be medication costs (figure 3). Overall, about 3700 SPC (ie, losartan/hydrochlorothiazide) would be prescribed, in place of monotherapeutic ARB and TD pills (online supplemental table 6).

Only SPC dispensation

Only SPC dispensation could increase the medication coverage by 10.3% (8.3%; 12.3%) compared with the base scenario (figure 2 and online supplemental figure 2). While the medication costs (0.39 rupees per patient and day (95% UI 0.39; 40)) could be comparable to the base scenario, the total costs (0.61 (95% UI 0.60; 0.62)) were lower due to the reduced dispensation costs (figure 3). A total of 22 700 (95% UI 22 100; 23 300) SPC pills could be dispensed, of which about 60% being telmisartan/amlodipine and the rest losartan/hydrochlorothiazide (online supplemental table 6).

Combined reforms

Combining focused procurement and increased SPC use could increase the medication coverage by 20.2% (18.3%; 22.1%) compared with the base scenario (figure 2 and online supplemental figure 2). The total cost was estimated at 0.56 (0.55; 0.57) rupees per patient a day, of which 0.34 (0.33; 0.35) rupees would be costs for medication and the rest being costs for dispensation (figure 3). About 46 000 pills could be dispensed, including some 5100 SPC (online supplemental table 6).

Extended prescription duration

Extended prescription period, from 1 to 2 or 3 months, was estimated to considerably increase the medication coverage regardless of medication procurement reforms (1 vs 3 months are compared in figure 2 and 2 months is shown in online supplemental figure 2). Estimated number of patients treated across these three periods is shown in online supplemental figure 3. For example, without other reforms, increasing prescription duration from 1 to 3 months (ie, quarterly supplies) could increase medication coverage by 38.9% (33.8%; 43.7%) without exceeding the total budget (figure 2 and online supplemental figure 2). The total cost per patient a day (0.48 (95% UI 0.46; 0.51) rupees) could be considerably lower than the base scenario due to lower dispensation costs (figure 3 and online supplemental figure 4), allowing ~60 000 pills being dispensed every month, compared with ~42 000 in the base scenario (online supplemental table 7).

The greatest increase in medication coverage was estimated for the combination of extended prescription duration (ie, 3 months periods), focused procurement and increased SPC use, which could increase the medication coverage by 61.8% (56.6%; 67.1%) compared with the base scenario (figure 2 and online supplemental figure 2). The total cost (0.42 (0.40; 0.43) rupees per patient and day) was the lowest estimated of all evaluated scenarios, with medication costs constituting around 80% of the total cost (figure 3). It was estimated that ~60 000 pills could be dispensed per month, including ~7000 SPC pills (online supplemental table 7).

Sensitivity analysis

Compared with the main analysis, the deterministic sensitivity analyses assumed higher or lower medication prices (defined as the maximum and minimum, respectively, of procurement prices reported by ≤9 states); 20% higher or lower dispensation costs; or equal dispensation costs (ie, 8.5 rupees per occasion) in all scenarios. Across the different deterministic sensitivity analyses conducted, in general, the combination of focused procurement and increased SPC consistently resulted in the greatest increase in medication coverage compared with the base scenario (online supplemental figure 5).

DISCUSSION

This simulation study suggests that medication procurement and dispensation reforms have the potential to substantially increase medication coverage for hypertension (ie, the number of patients receiving medication) despite a fixed budget. For example, a reform of focused procurement of fewer medication types and classes alone or together with greater use of SPC could increase the medication coverage by ~20% compared with the base scenario. The impact of extended prescription period was

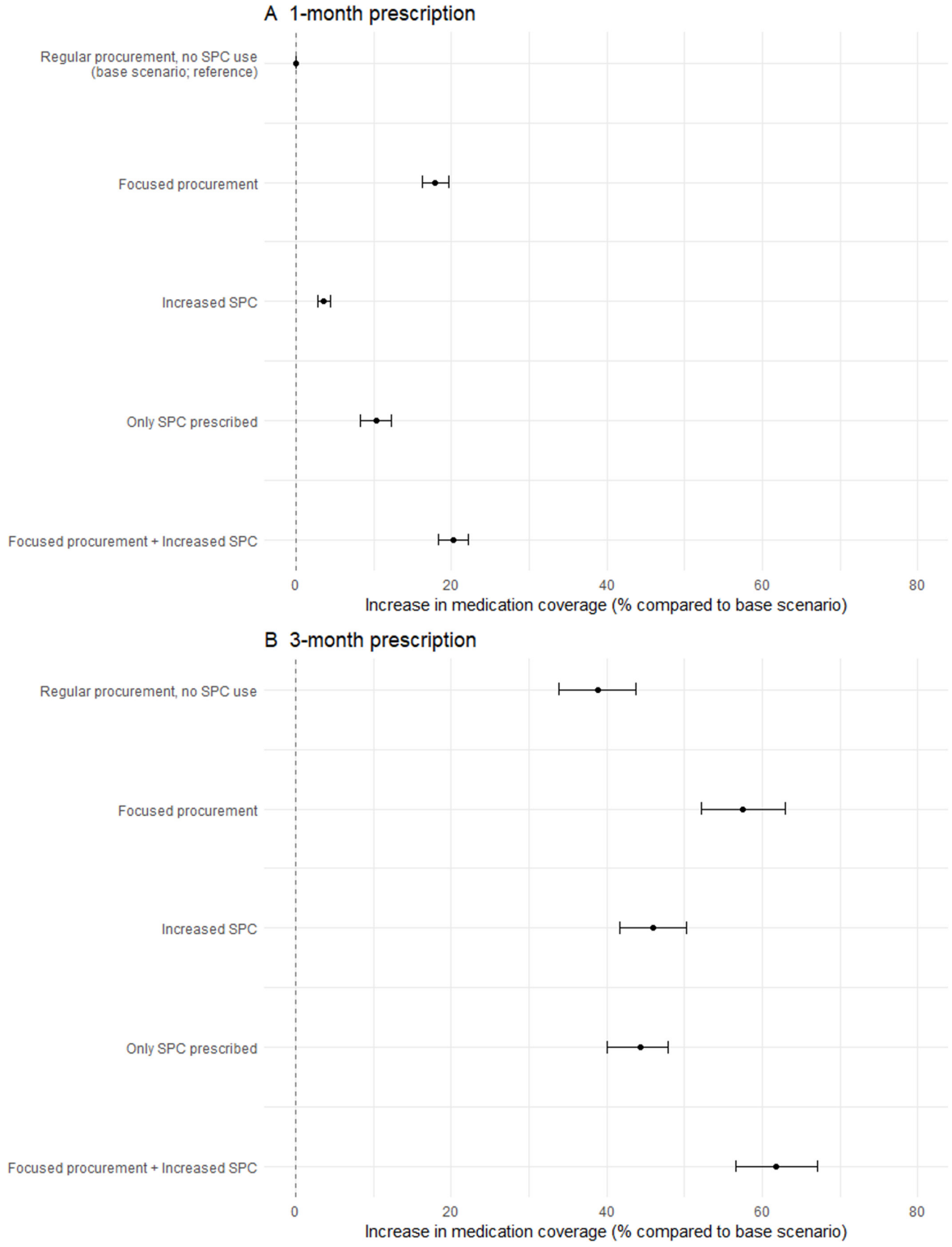

Figure 2 Estimated impact on medication coverage, assuming patients are dispensed medication for either 1-month periods (A) or 3-month periods (B). The black vertical lines represent the base scenario, where n=1000 patients are dispensed 1-month prescriptions (no SPCs) at regular procurement prices. In focused procurement scenarios, ACE-I and BB medication classes are excluded. The additional medication coverage is expressed as the percentage increase in patients treated with sufficient medication, compared with the base scenario. The largest increase in coverage (~60%) is observed when combining focused procurement, increased SPC use and 3-month prescription durations. BB, beta blocker; SPC, single pill combination.

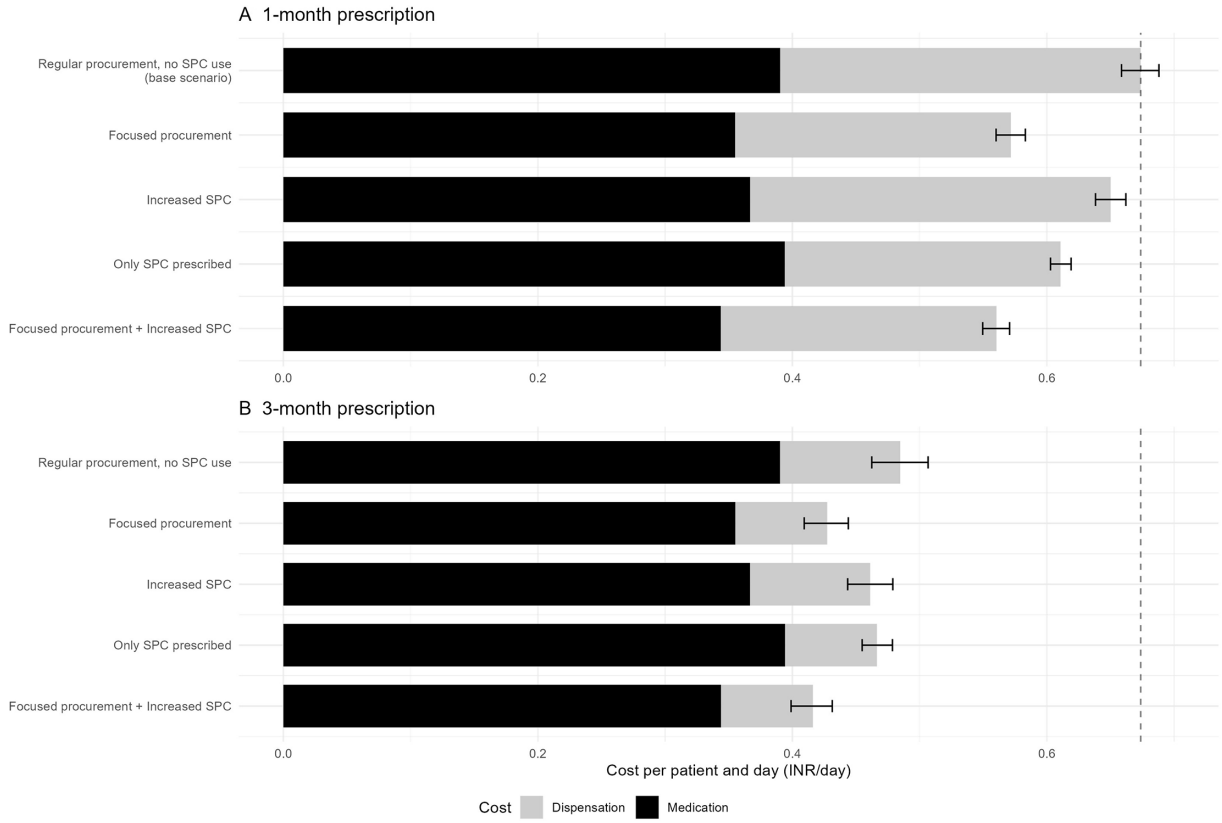

Figure 3 Estimated total cost per patient per day, assuming patients are dispensed medication for either 1-month periods (A) or 3-month periods (B). Total costs include medication costs (grey) and dispensation costs (white). The vertical dashed line represents the mean cost of the base scenario, where patients receive 1-month prescriptions at regular procurement prices without SPCs. Error bars indicate the 95% uncertainty intervals of total costs. In focused procurement scenarios, ACE-I and BB classes are excluded, and price reductions are assumed due to increased procurement volumes. Extended prescription durations reduce dispensation costs, contributing to overall lower total costs. The largest reduction in total cost (~37%) is observed when combining focused procurement, increased SPC use and 3-month prescription durations, and the reduction is mainly due to lower dispensation costs. BB, beta blocker; SPC, single pill combination.

substantial. Specifically, with the combination of focused procurement, increased SPC use and 3-month prescription period, the medication coverage could increase by ~60% compared with the base scenario.

Focused procurement alone was estimated to increase medication coverage by ~20% compared with the base scenario, by reducing unit prices of selected medications. An increase in medication coverage of this magnitude could have substantial impact on hypertension care in India, where only 15% with hypertension are under treatment. Many popular antihypertensive medications in India are already heavily discounted for public procurement. For example, the mean public procurement price of amlodipine in nine Indian states is 0.12 rupees per pill vs 0.55 rupees per pill, which is what patients would pay in pharmacies under the government's Jan-Aushadhi scheme or 2.8 rupees per pill in the private sector.[16] Thus, it is possible that focused procurement reforms could have an even greater impact in regions of India and countries with less discounted procurement prices. For example, Yuan *et al* demonstrated 55%–83% medication price reductions off of list price following a national volume-based procurement pilot in China.[17] A similar approach in India could amplify the benefits seen in our study by further leveraging bulk purchasing agreements to reduce prices and enhance access.[18] While the already discounted procurement prices may limit the impact on medication costs from focused procurement in this study, the reduced number of medications to be stored and dispensed could reduce the workload of pharmacists, thereby reducing the dispensation cost per patient.

Increased SPC use alone and only SPC dispensation each increases medication coverage by ~5%–10% compared with the base scenario. However, the impact may have been limited by the relatively high cost per pill for SPC products compared with the lowest cost medications (amlodipine, atenolol, hydrochlorothiazide).[19] For example, one SPC pill of amlodipine/telmisartan was more expensive than the combination of one amlodipine pill and one telmisartan pill. Similar findings were reported for several other LMICs (ie, Brazil, Nigeria, South Africa and the Philippines), where the dual-drug SPC with the lowest cost was consistently priced higher than the sum of the two single-agent pills with lowest cost.[20] The reason for this counterintuitive cost structure appears to be related to the limited number of competing

companies that manufacture SPC pills. In the USA, the median price of a generic drug with only one manufacturer is around 60% of the brand drug, whereas generics with ≥6 competing manufacturers have median prices <10% of the brand drugs,[21] and thus it is possible that unit prices of SPC will decrease with more manufacturers making their generic SPC products available for public procurement. A reduction in procurement prices, to at least the same price as the equivalent multipill alternatives, may indeed be needed to allow widespread use of SPC for public sector hypertension care in India.[19]

Increasing prescription duration had the greatest impact on all reforms that we examined. By changing dispensation from 1-month to 3-month prescriptions, medication coverage increased substantially (about 40%–60% depending on the procurement approach). This gain in medication coverage by 3-month dispensation was driven by reducing the labour costs of pharmacists for each patient (ie, medications dispensed only every third month, instead of on a monthly basis). Evidence from other healthcare settings indicates that longer prescription durations can reduce dispensing costs and administrative burden by lowering the frequency of patient visits for refills. For instance, a systematic review and economic modelling study suggested that longer prescriptions could considerably save costs by reducing prescribers' time and pharmacist dispensing fees.[22] As we recently reported, an increase in prescription period could also reduce the burden of other healthcare providers like physicians and nurses and could allow the current hypertension-treating workforce in India's public health system to treat about three times as many patients.[23] Importantly, during the COVID-19 pandemic, patients with hypertension and other chronic disease in India were able to receive their prescribed medications for 3-month periods.[24] Although longer prescription may appear to require an enriched medication supply, once the system is stabilised, theoretically the number of medications needed is identical regardless of prescription period (eg, 900 patient×30 days=300 patients×90 days). Thus, a greater budget and medication supply are only needed during the transition from monthly to quarterly prescriptions.

Beyond increasing medication coverage, these reforms can improve both patient and provider experiences. The availability of SPCs in the public sector simplifies treatment regimens by reducing the number of pills patients take daily. This may improve convenience, enhance adherence and foster better health outcomes, which ultimately could increase patient satisfaction and confidence in the public health system. For providers, SPCs streamline treatment protocols, reduce the complexity of prescribing and dispensing medications, and empower healthcare professionals to deliver more effective care, reinforcing the system's commitment to equity and quality. Similarly, focused procurement can improve medication availability by reducing the risk of stockouts and ensuring reliable access to essential treatments for patients. For pharmacists and clinic staff, standardised procurement of fewer medications simplifies inventory management, lowers administrative burdens and reduces the risk of dispensing errors, ultimately improving workflow efficiency in resource-limited settings. Additionally, longer prescription durations offer notable societal benefits. Specifically, reduced clinic visit frequency can reduce patients' travel and visit time, save transportation costs, minimise work disruptions and ease burdens on caregivers. These advantages are particularly relevant for patients in rural or underserved areas and those managing chronic conditions. Although our analysis did not account for these broader societal benefits, future studies could explore them in greater detail to provide a more comprehensive evaluation of these reforms and their potential impact on equity and access in the public health system.

The proposed reforms, however, are not without challenges that may hinder implementation. For instance, transitioning to extended prescription durations may require greater upfront budgets and increased medication supply, factors that are not relevant at steady state, but could place additional strain on systems already struggling to maintain 1-month supplies. Strengthening supply chains, improving inventory management and implementing buffer stock strategies will be essential to mitigate this risk. Other challenges include potential provider resistance to focused procurement and increased SPC use, as these strategies may be deemed limiting personalised treatments. Additionally, some patients may resist extended prescription periods due to reduced opportunities for interaction with healthcare providers. The increased use of SPCs may also face initial resistance from pharmaceutical companies concerned about lower per-unit prices and shifts in demand away from single-agent products. However, higher total sales volumes driven by broader SPC uptake could ultimately benefit both manufacturers and public health systems. Finally, regulatory barriers, including updates to treatment guidelines and essential medicines lists, may further delay adoption. Addressing these challenges will require strong policy support, proactive stakeholder engagement and coordinated efforts to ensure the reforms' sustainability and impact.

Our study has limitations. First, we considered only direct costs for procuring and dispensing medications, but not other related potential costs, for example, additional costs for transporting and storing an increased volume of medications. Also, in only SPC dispensation, we did not take into account costs related to additional workload of pharmacists to prepare a half pill for some patients. Second, our model focused on a clinic or health system perspective and did not account for societal costs such as patient travel time, loss of productivity or caregiver time.

Third, when relevant data were unavailable, we decided parameters based on our experience or observation. Nonetheless, our results were robust in various sensitivity analyses.

Our study has several policy implications. First, while the improvement of medication coverage by ~60% with these reforms is large, we should acknowledge that these reforms alone cannot completely solve the low control rate of hypertension (~15%) in India. However, the reforms assessed in the present study focus on medication procurement/dispensation and can be combined with other reforms such as enhancing task-sharing, medication adherence support and efforts to retain patients in care.[5 25] Second, our findings support the protocol-driven treatment of hypertension with 3–4 medications and increasing use of SPC endorsed by WHO and Resolve to Save Lives.[8 15] Finally, while the current study focused on medications for hypertension, these reforms are likely applicable to medication coverage for other chronic conditions in India and elsewhere.

CONCLUSIONS

The combination of focused procurement, increased SPC use and extended prescription periods could substantially increase the number of patients who receive hypertension medications in India's public health system. Of note, this substantial increase is achievable with a fixed budget for medication procurement and dispensation, and thus policy-makers and healthcare system leaders should consider implementing these reforms. The benefit of increased SPC use relies on its price, and thus expert organisations should advocate for affordable pricing of SPCs. These reforms have the potential to significantly scale up medication coverage for hypertension in India and serve as a model for other resource-limited settings.

Author affiliations
[1]Department of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, USA
[2]Welch Center for Prevention Epidemiology and Clinical Research, Johns Hopkins University, Baltimore, Maryland, USA
[3]The George Institute for Global Health, UNSW Sydney, Sydney, New South Wales, Australia
[4]Department of Public Health and Caring Sciences, Clinical Nutrition and Metabolism, Uppsala University, Uppsala, Sweden
[5]Department of Pharmacotherapy, The University of Utah College of Pharmacy, Salt Lake, Utah, USA
[6]Resolve to Saves Lives, New York, New York, USA
[7]Isaac Centre for Public Health, Indian Institute of Science, Bengaluru, India
[8]Columbia University Irving Medical Center, New York, New York, USA
[9]Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, USA
[10]Johns Hopkins School of Medicine, Baltimore, Maryland, USA

X Matti Marklund @MarklundMatti and T Joseph Mattingly II @joeymattingly

Contributors MM, TJM, LJA and KM conceived and designed the work; acquired, analysed and interpreted the data; drafted, revised and approved the final manuscript. SKS, PK and AM interpreted the data; revised and approved the final manuscript. The authors used AI technology (OpenAI's ChatGPT-4) to improve clarity and readability in minor parts of the manuscript. All AI-generated outputs were reviewed and validated by the authors. MM is responsible for the overall content as guarantor.

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ORCID iDs
Matti Marklund http://orcid.org/0000-0002-3320-796X
T Joseph Mattingly II http://orcid.org/0000-0001-7786-5780
Prabhdeep Kaur http://orcid.org/0000-0002-2605-3739

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