doi.org/10.36721/PJPS/2026.40.16714.1

Construction of a county-town-village three-level drug distribution system in county-level medical consortia: A palliative care opioid analgesic model from Huzhou city, Zhejiang province, China

Hongwu Wang[1], Caiying Zhang[2] and Ting Zhu[3]*

[1]Department of General Practice, Deqing County People's Hospital, Huzhou, 313200 Zhejiang, China
[2]Department of Pediatrics, Deqing County People's Hospital, Huzhou 313200 Zhejiang, China
[3]Department of Oncology and Hematology, Deqing County People's Hospital, Huzhou 313200 Zhejiang, China

Abstract: **Background**: In county-level and rural regions of China, access to opioid analgesics for palliative care is constrained by centralized dispensing, fragmented drug distribution systems and limited patient mobility. Although county-level medical consortia have strengthened healthcare integration, an evidence-informed framework for the decentralized yet regulated distribution of controlled medicines remains insufficiently developed. **Objectives**: This study aimed to develop and evaluate, through simulation-based policy modeling, a County–Town–Village (CTV) three-level drug distribution framework for opioid analgesics within county-level medical consortia using Zhejiang Province as a conceptual case study. **Methods**: A simulation-based comparative policy analysis was performed using structured simulated data representing 12 modeled county-level medical consortia (six intervention and six comparison counties) over a simulated 12-month period. Simulation inputs were generated from plausible county-level healthcare characteristics, opioid prescribing patterns, travel distances and pharmaceutical governance indicators. Difference-in-differences (DiD) analysis was applied to compare projected outcomes between simulated scenarios, including medication access time, travel distance, continuity of opioid use, documentation completeness, adverse drug event reporting and diversion-risk indicators. **Results**: The modeled intervention projected shorter medication access time (DiD = −3.0 days; $p < 0.001$), reduced travel distance (DiD = −24.9 km/month; $p < 0.001$), improved continuity of opioid use (70.8% to 84.9%; DiD = +12.7 percentage points; $p < 0.001$) and greater documentation completeness (61.3% to 88.9%; $p < 0.001$). Simulated adverse drug event reporting increased (5.9 to 8.4 per 100 patient-months; $p = 0.012$), whereas diversion-risk indicators remained unchanged (1.8% vs. 1.9%; $p = 0.74$). **Conclusion**: This simulation-based policy evaluation suggests that the proposed three-level distribution framework may improve access, continuity and pharmaceutical governance of opioid analgesics while maintaining regulatory oversight under modeled conditions. Because these findings are simulation-derived rather than empirically observed, prospective real-world implementation studies are required before policy adoption.

Keywords: County-level medical consortia; County–Town–Village three-level system; Opioid analgesics; Palliative care; Pharmaceutical governance; Simulation modeling

Submitted 01-05-2026 – Revised 24-07-2026 – Accepted 27-07-2026

Article in Press

INTRODUCTION

Medicines are fundamental to effective healthcare systems and their availability, safety and continuity of supply directly influence clinical outcomes and patient well-being (Ahmed and Tamim, 2025; Al-Worafi, 2023). Among essential medicines, opioid analgesics are indispensable for the management of moderate-to-severe pain in patients receiving palliative care, particularly those with advanced cancer and end-stage chronic diseases (Pei *et al.,* 2026; Sanjuda *et al.,* 2022).

However, because opioid analgesics are controlled medicines, their procurement, storage, prescribing, dispensing and monitoring are subject to stringent regulatory requirements intended to ensure both patient access and prevention of misuse or diversion (Hemmeda *et al.,* 2023; Jackson *et al.,* 2022). Balancing these two objectives remains a major challenge for healthcare systems, particularly in county-level and rural regions of China, where pharmaceutical resources and healthcare infrastructure are often unevenly distributed (Shakya and Ruseski, 2023; Sun, 2022).

In several county-level health systems, opioid analgesics are still mostly supplied through county hospitals, ranging from large concentrated facilities (Fan *et al.,* 2026). While this model improves regulatory oversight, it can diminish access when timely treatment for patients needing chronic opioid therapy is required, with multiple trips to county hospitals increasing financial and physical stressors whilst contributing to a breaking of continuity (Pham *et al.,* 2024; Shannon *et al.,* 2026). As a result, it has become a key goal of continued health system reform to balance improving access to opioid analgesics with the desire for improved pharmaceutical governance.

**Corresponding author:* e-mail: angzi213317@126.com

For instance, China has established county-level medical consortia to enhance the coordination between county hospitals and township health centers as well as village clinics (An *et al.,* 2025). Studies to date have largely explored referral pathways, integration and delivery of services within consortia (Gao *et al.,* 2022). However, notably less attention has been paid to organizational strategies for pharmaceutical supply chain/distribution specifically for the types of controlled medicines which drive both positive and negative changes in utilization patterns that measure accessibility alongside traceability, regulatory compliance and diversion prevention (Oyri and Wiig, 2022; Natali *et al.,* 2023; Yang and Mishra, 2025).

Importantly, tiered CTV healthcare structures have previously been described within China's healthcare system (Dong *et al.,* 1999). However, existing models primarily address healthcare organization or pharmaceutical distribution in general rather than providing a structured pharmaceutical governance framework specifically designed for regulated opioid analgesic distribution within county-level medical consortia. Moreover, previous reports have not systematically evaluated how coordinated pharmaceutical governance, township-level dispensing, village-level follow-up and regulated home delivery could function together within an integrated distribution pathway for palliative care. This represents the principal knowledge gap addressed by the present study.

Previous research primarily described pharmaceutical distribution within rural healthcare systems, the present study develops and evaluates a simulation-based pharmaceutical governance framework integrating regulated opioid dispensing, township-level distribution, regulated home delivery, electronic traceability and coordinated village-level follow-up within county-level medical consortia (Dong *et al.,* 1999).

Rather than proposing an entirely new healthcare structure, this study develops a conceptual pharmaceutical governance framework that integrates existing CTV healthcare infrastructure with standardized pharmaceutical management, closed-loop traceability, regulated home delivery and coordinated follow-up for opioid analgesics. Because real-world implementation data are currently unavailable, the proposed framework was evaluated using simulation-based policy modeling to examine its potential operational performance under plausible county-level healthcare conditions. Such simulation approaches provide an opportunity to explore the feasibility and potential impact of alternative healthcare policies before large-scale implementation while identifying important operational considerations for future empirical evaluation (Kim, 2024).

Zhejiang Province was selected as a representative policy context because of its substantial rural population, ongoing development of county-level medical consortia and persistent differences in pharmaceutical service capacity between county hospitals and primary healthcare institutions (Gao *et al.,* 2022; Zhu *et al.,* 2025). The province therefore serves as a conceptual case study for evaluating how the proposed pharmaceutical distribution framework might operate under realistic county-level conditions rather than representing a completed real-world implementation.

Simulation-based policy modeling has emerged as a particularly attractive framework for evaluating complex healthcare system interventions when the feasibility, resource intensity, or regulatory requirements of prospective implementation render it impractical (Cha *et al.,* 2025). Simulation combines data from published literature with realistic operational assumptions to explore the potential impacts of alternative healthcare policies (when and how they might be implemented), facilitating population-level policy comparisons before widespread implementation. These methodologies act as complementary sources of initial evidence for future prospective studies and facilitate decision-making in developing evidence-based health-care plans (Demir *et al.,* 2024).

The present study differs from previous investigations by focusing on pharmaceutical governance rather than healthcare organization alone. Instead of introducing a new CTV healthcare structure, it develops and evaluates a coordinated governance framework that integrates opioid dispensing, pharmaceutical traceability, inventory management, regulated home delivery and multidisciplinary follow-up within the existing county-level medical consortium system (Feng *et al.,* 2024). To the best of current knowledge, few previous studies have systematically assessed this integrated pharmaceutical governance strategy for controlled medicines using a simulation-based policy-modeling approach (Sokolovska and Klepikova, 2024; Ward *et al.,* 2024).

Accordingly, the objective of this simulation-based policy-modeling study was to develop and evaluate a CTV three-level pharmaceutical distribution framework for opioid analgesics within county-level medical consortia. Specifically, the study simulated coordinated pharmaceutical governance, township-level dispensing, village-level follow-up and regulated home delivery to estimate their potential effects on medication accessibility, treatment continuity, pharmaceutical governance and drug safety indicators. The findings are intended to provide preliminary policy evidence and generate hypotheses for future prospective implementation studies rather than to demonstrate real-world effectiveness.

Article in Press

MATERIALS AND METHODS

Study design

This study employed a simulation-based comparative policy-modeling design to develop and evaluate a conceptual CTV three-level pharmaceutical distribution framework for opioid analgesics within county-level medical consortia. The study was designed to assess the operational feasibility and projected policy impact of the proposed distribution framework under realistic county-level healthcare conditions before potential real-world implementation.

Unlike an empirical clinical or quasi-experimental study, no patients, healthcare professionals, healthcare institutions, or operational datasets were involved. Instead, structured simulated datasets were generated using predefined healthcare system assumptions derived from published literature, national pharmaceutical regulations and commonly reported operational characteristics of county-level healthcare services in China.

Two policy scenarios were constructed for comparison. The intervention scenario represented implementation of the proposed CTV pharmaceutical distribution framework, whereas the comparison scenario represented the conventional county hospital-based opioid dispensing model currently used in many county-level healthcare systems. Both scenarios were evaluated over an equivalent simulated 12-month observation period.

Projected policy outcomes were evaluated using a DiD analytical framework to estimate the relative effect of the proposed pharmaceutical governance model while accounting for baseline differences and temporal variation between simulated scenarios. The objective of the analysis was to compare projected system performance rather than estimate actual clinical effectiveness.

Study setting

Zhejiang Province, China, was selected as the conceptual policy context because of its predominantly rural population, heterogeneous geographical characteristics and continuing implementation of county-level medical consortia. These characteristics provide a representative environment for evaluating pharmaceutical distribution challenges commonly encountered in county-level healthcare systems, including limited healthcare accessibility, long travel distances and differences in pharmaceutical service capacity between county hospitals and primary healthcare institutions (Gao *et al*., 2022; Zhu *et al*., 2025).

The province served exclusively as a conceptual policy case study for simulation purposes. No healthcare organizations, healthcare professionals, pharmacies, or patients from Zhejiang Province participated in this research and no real-world operational or clinical data were collected.

Within the conceptual framework, each modeled county-level medical consortium consisted of one county hospital, several township health centers and affiliated village clinics, reflecting the organizational structure widely adopted within China's healthcare system. Under the conventional policy scenario, opioid analgesics were dispensed exclusively through county hospitals. Under the proposed policy scenario, qualified township health centers were additionally authorized to dispense opioid analgesics under centralized county-level pharmaceutical governance, while village clinics provided structured medication follow-up and patient support.

Conceptual framework of the CTV pharmaceutical governance model

- Conceptual CTV distribution framework: The proposed CTV pharmaceutical distribution framework was developed as a conceptual pharmaceutical governance model intended to improve accessibility to opioid analgesics while maintaining regulatory compliance for controlled medicines. Rather than introducing a new healthcare organizational structure, the framework integrates the existing ctv healthcare network with standardized pharmaceutical governance procedures, closed-loop medication traceability, regulated home delivery and coordinated multidisciplinary follow-up.

- County-level pharmaceutical governance: County hospitals served as the central pharmaceutical governance units responsible for procurement planning, inventory management, formulary control, prescribing authorization, pharmaceutical auditing, professional training and stock reconciliation. The county hospital pharmacy maintained reserve inventories of opioid analgesics and supervised medication allocation to qualified township health centers according to standardized operating procedures. Routine inventory reconciliation and dispensing audits were incorporated to strengthen accountability and compliance with controlled-drug regulations (Smith, 2024).

- Township-level dispensing and clinical monitoring: Qualified township health centers were modeled as secondary dispensing units after meeting predefined pharmaceutical governance requirements, including licensed pharmacy personnel, secure storage facilities, standardized electronic dispensing documentation and routine pharmaceutical supervision. Township pharmacists were responsible for prescription verification, dosage confirmation, medication dispensing, patient counseling and coordination of regulated home delivery. Township

Article in Press

physicians conducted scheduled pain assessments, monitored treatment response, evaluated adverse drug reactions and adjusted opioid therapy during outpatient visits or telemedicine consultations.

Village-level medication follow-up: Village clinics did not provide opioid analgesics. On the contrary, they were actually community drug dispensing support hubs that monitored medication compliance, assessed storage conditions, recognized early warning signs of negative effects or inappropriate use of opioids and strengthened patient education and follow-up with township health centers. This method reinforced continuity of pharmaceutical care while not increasing prescribing or dispensing authority.

Regulated home delivery procedures: Within the simulated intervention scenario, regulated home delivery was available only for eligible palliative care patients meeting predefined criteria, including limited mobility, stable opioid dosage requirements, confirmed caregiver support and physician authorization for home-based medication management.

The conceptual delivery pathway incorporated tamper-evident packaging, serialized medication identifiers, dual verification before dispatch by pharmacy personnel, secure transportation procedures, patient or caregiver identity verification at delivery and mandatory electronic documentation of receipt. Each delivery event was linked electronically to prescribing, dispensing, transportation and follow-up records to maintain complete medication traceability throughout the pharmaceutical supply chain. Home delivery remained under the supervision of county-level pharmaceutical governance and was intended to improve medication accessibility while preserving regulatory oversight of controlled medicines (Fig. 1).

Simulation model development

A conceptual simulation model was developed to evaluate the projected operational performance of the proposed CTV pharmaceutical distribution framework under realistic county-level healthcare conditions. The model represented the complete pharmaceutical pathway for opioid analgesics, including prescribing, procurement, inventory allocation, dispensing, regulated home delivery, medication follow-up, adverse event monitoring and pharmaceutical governance. Using a systems-based policy-modeling approach, healthcare processes were represented as sequential operational events occurring within county hospitals, township health centers and village clinics. Each simulated county-level medical consortium operated independently while following identical pharmaceutical governance standards and regulatory procedures.

Two policy scenarios were modeled. The intervention scenario incorporated decentralized opioid dispensing through qualified township health centers together with regulated home delivery and village-level follow-up, whereas the comparison scenario represented the conventional county hospital-centered dispensing model without decentralized pharmaceutical services. Both scenarios were simulated over identical observation periods to permit direct comparison of projected policy outcomes. The model assumed compliance with China's existing regulatory framework for controlled medicines, with standardized pharmaceutical governance procedures applied consistently across the intervention scenario. No changes were made to opioid prescribing indications, prescribing authority, or national regulations; only the organization of pharmaceutical distribution and medication management differed between policy scenarios (Cha *et al*., 2025).

Data sources and simulation strategy

Patient-level clinical data or other operational records were not used. Instead, simulated datasets of structured data were generated to capture realistic county-level healthcare settings based on published evidence, national pharmaceutical dispensing policies, registry reports of healthcare utilization at the county level and expert-informed operational assumptions about innately available common functional pathways. Not meant to reproduce any real clinical results, the simulation was conducted exclusively to examine whether the proposed pharmaceutical distribution framework was at all viable and what may be expected. Estimates of the volume were incorporated into the simulation model of palliative care patients, the frequency and interval at which opioids are prescribed and filled, demand for medications in the community, distance to travel for adherence (if any), compliance with appropriate clinical documentation practices, adverse drug event reporting rates and other diversion-risk indicators.

The simulated observation period covered 12 months, comprising a six-month baseline period representing the conventional county hospital-based distribution model and a six-month post-policy period representing implementation of the proposed CTV pharmaceutical distribution framework. Identical baseline conditions were applied to the intervention and comparison scenarios to ensure comparability before policy implementation. Simulation outputs were evaluated at the patient-month level to assess medication access, treatment continuity, pharmaceutical governance and medication safety throughout the observation period (Noto *et al*., 2025).

Article in Press

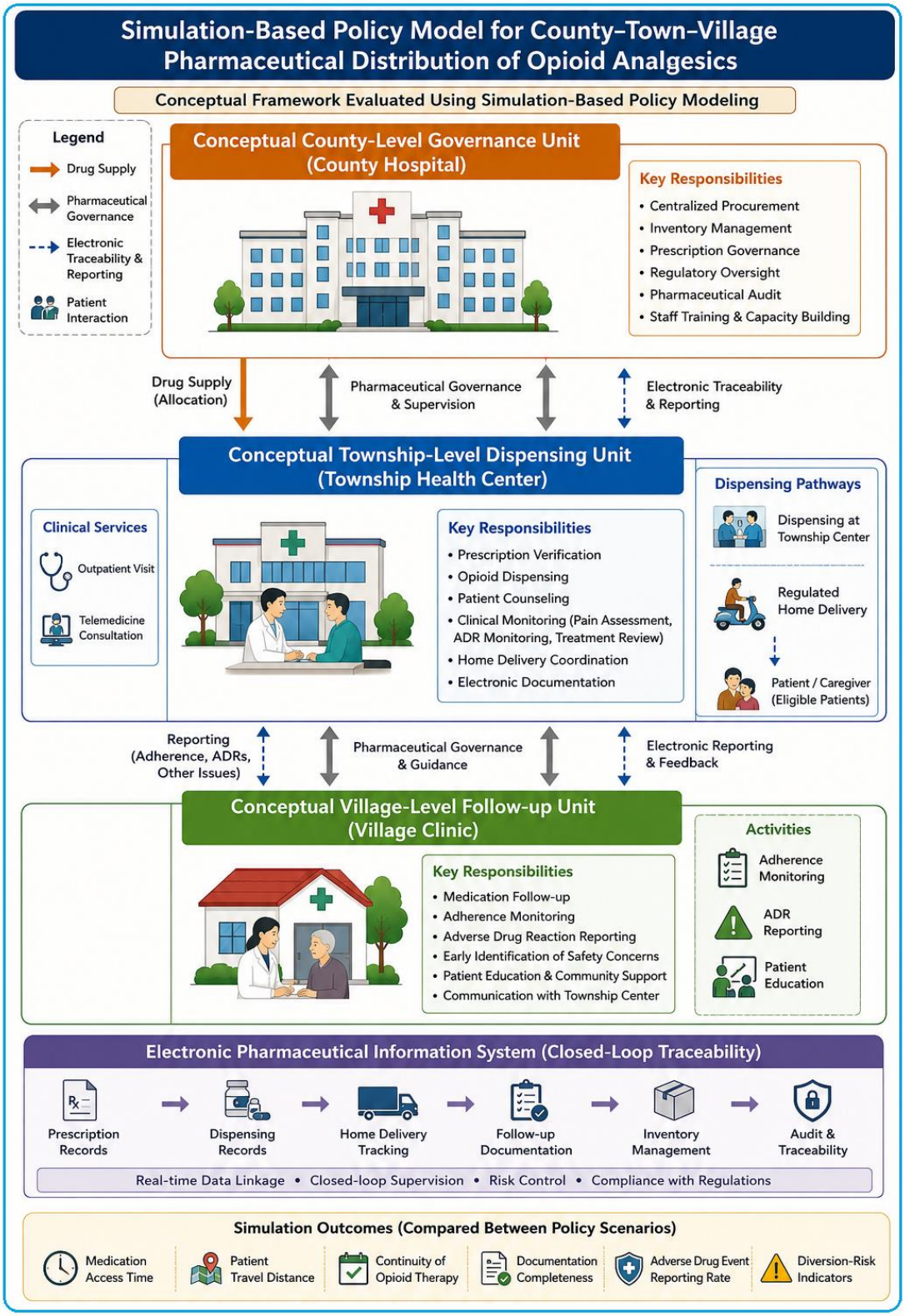


Fig. 1: The conceptual architecture of the CTV pharmaceutical distribution framework under county-level medical consortia. It summarizes the contributions of county hospitals, township health centers and village clinics to pharmaceutical governance, including opioid dispensing, inventory management, regulated home delivery from hospital- or clinic-based pharmacies, patient follow-up on tapering schedules and medication traceability. This figure represents a simulation model and not an actual implemented/implied system.

Simulation assumptions

The use of predefined assumptions consistent with published policy-modeling recommendations in developing the simulation model increased transparency and reproducibility. The model assumed no changes to the organizational structure of each county-level medical consortium; stability in the number of patients who would benefit from opioid analgesics; and that treatment patterns conformed to nationally approved clinical guidelines regardless of policy scenario. The regulatory framework qualified township health centers for controlled medicines; village clinics prescribed and dispensed medications but did not prescribe and dispense opioids, support or follow up on people's opioid use; and regulated home delivery was established only for eligible patients with a physician for regulatory approval, stable therapy, reduced mobility and caregiver support.

The study also assumed that there would be no interruptions to electronic pharmaceutical information systems, implementation of standardized pharmaceutical governance training for healthcare staff and no major shifts in policy that could affect opioid regulations throughout the simulation. Non-routine operating conditions such as exceptional events (including medication shortages, natural disasters and transportation disruptions) were excluded from the analysis. Such conservative assumptions provided for a standardized comparison of policy scenarios, while reducing systematic external confounding; thereafter, they were tested through sensitivity analyses to evaluate the strength of resulting projections (Crosland *et al*., 2024).

Study population

Because this investigation was a simulation-based policy-modeling study, no actual patients were recruited. Instead, a modeled population was constructed to represent adult patients who would typically receive palliative care and require opioid analgesics for the management of moderate-to-severe pain within county-level medical consortia. The simulated population reflected commonly reported demographic and clinical characteristics of patients with advanced cancer or end-stage chronic diseases requiring long-term opioid therapy.

Simulated inclusion criteria comprised adult patients (≥18 years) with a clinical indication for opioid analgesic treatment for palliative care, enrollment within a modeled county-level medical consortium and eligibility for continued opioid therapy according to national clinical practice guidelines. Patients receiving short-term postoperative opioid therapy, those without palliative care indications and individuals requiring opioid treatment for acute non-palliative conditions were excluded from the simulated population.

Patient characteristics remained comparable between the intervention and comparison scenarios during the baseline simulation period to ensure that projected differences reflected changes in pharmaceutical distribution rather than differences in population composition.

Outcome measures

Outcome measures were selected to evaluate three principal domains of pharmaceutical service performance: medication accessibility, treatment continuity and pharmaceutical governance. Outcome definitions were standardized before simulation to ensure consistent evaluation across both policy scenarios. Primary outcomes included medication access time (days), defined as the projected interval between prescription authorization and receipt of opioid analgesics; patient travel distance (km/month), representing the cumulative monthly travel required to obtain medication; and continuity of opioid therapy (%), calculated as the projected proportion of treatment days covered by dispensed medication using medication possession principles.

Secondary outcomes assessed pharmaceutical governance and medication safety, including documentation completeness (%), adverse drug event reporting rate (per 100 patient-months) and diversion-risk indicators (%), defined as the proportion of medication episodes triggering predefined governance alerts such as early refill requests, documentation discrepancies, interrupted medication traceability, or inconsistencies identified during follow-up. Outcome definitions were identical across both simulated policy scenarios to permit unbiased comparison of projected intervention effects.

Statistical analysis

Simulated baseline characteristics and estimated outcome measures were summarized using descriptive statistics. Continuous variables were summarized as means ± standard deviations (SD) for characteristics that appeared normally distributed or medians with interquartile ranges (IQR) if not normally distributed. Categorical data were expressed as frequency and percentage. All statistical analyses were performed using Stata Statistical Software, version 18 (StataCorp LLC, College Station, TX, USA).

The primary analytical approach was DiD regression, which estimated the projected policy effect of the CTV pharmaceutical distribution framework by comparing changes in outcome measures between the intervention and comparison scenarios before and after simulated implementation. The DiD estimator was calculated as the difference between temporal changes observed in the intervention scenario and those observed in the comparison scenario.

Model assumptions included comparable baseline trends between simulated scenarios, consistent observation

Article in Press

periods and stable healthcare system characteristics other than the pharmaceutical distribution framework being evaluated. Because simulation inputs were generated using identical baseline conditions, these assumptions were considered satisfied within the policy-modeling environment.

Projected effect estimates were reported together with 95% confidence intervals (95% CI) and corresponding p-values. A two-sided p-value < 0.05 was considered statistically significant. All statistical analyses were performed using Stata Statistical Software, Release 18 (StataCorp LLC, College Station, TX, USA). Panel-data analytical procedures appropriate for repeated observations generated from simulated healthcare system scenarios were applied.

Sensitivity analysis

To evaluate the robustness of projected findings, deterministic sensitivity analyses were conducted by systematically varying key simulation parameters within clinically plausible ranges derived from published literature and healthcare policy reports. Parameters examined included palliative care patient volume (±20%), medication demand (±15%), travel distance (±20%), documentation compliance (±15%), adverse drug event reporting (±20%) and diversion-risk indicators (±15%). Additional scenario analyses evaluated the influence of reduced township pharmacy capacity, delayed medication transportation, incomplete electronic documentation and lower patient eligibility for regulated home delivery. For each alternative scenario, primary outcome measures were recalculated while maintaining identical analytical procedures.

The purpose of these analyses was not to estimate statistical uncertainty associated with empirical observations but to determine whether the projected benefits of the proposed pharmaceutical distribution framework remained consistent under varying operational assumptions. Stable results across alternative simulation scenarios were interpreted as supporting the robustness of the policy model (Ali *et al*., 2025).

Ethical and regulatory considerations

This study used exclusively simulation-generated datasets and publicly available information, without involving human participants, patient records, identifiable personal data, clinical interventions, or actual pharmaceutical distribution. Therefore, ethical approval and an associated approval number were considered not applicable, subject to institutional and journal requirements.

The simulation assumed uninterrupted pharmaceutical information systems, standardized staff training, and stable opioid regulations. Medication shortages, natural disasters, and transportation disruptions were excluded to ensure consistent scenario comparisons. The robustness of the projected outcomes was assessed through sensitivity analyses.

Before simulated implementation of the proposed policy model, baseline demographics and clinical characteristics were purposefully generated to ensure comparability between the intervention and comparison scenarios. The patient population was modeled with a mean age of 66.8 years and about three-quarters of patients were assumed to have advanced malignant disease requiring chronic opioid analgesic therapy. As shown in table 1, no between-group differences were statistically significant in terms of age, sex distribution, disease category, baseline opioid dose (OME), or baseline pain severity ($p > 0.05$), thus confirming adequate balance after randomization before the initiation of DiD analyses.

Figure 2 illustrates the conceptual closed-loop pharmaceutical governance framework incorporated into the simulation model, demonstrating the coordinated responsibilities of county hospitals, township health centers and village clinics for prescription governance, centralized procurement, medication dispensing, regulated home delivery, follow-up monitoring and pharmaceutical traceability.

Effects on medication accessibility

- ***Time to medication access***: Before simulated implementation of the proposed pharmaceutical distribution framework, the median time from physician prescription to receipt of opioid analgesics was comparable between the intervention and comparison scenarios (4.8 vs. 4.6 days; $p = 0.42$). Following simulated implementation, the projected median access time in the intervention scenario decreased substantially to 1.6 days, whereas only minimal change was observed in the comparison scenario (4.4 days).

DiD analysis estimated a projected reduction of 3.0 days in medication access time (DiD = −3.0 days; 95% CI: −3.6 to −2.4; $p < 0.001$), indicating that decentralization of opioid dispensing through qualified township health centers, together with regulated home delivery, was associated with a marked improvement in the timeliness of medication access under the simulated policy model (Table 2).

Figure 3 presents the projected DiD trends in median medication access time before and after simulated implementation of the proposed CTV pharmaceutical distribution framework.

- ***Patient travel distance***: The simulation projected a substantial reduction in patient travel burden following implementation of the proposed pharmaceutical distribution framework.

Article in Press

Table 1: Baseline characteristics of the simulated palliative care population in the intervention and comparison policy scenarios.

Characteristic	Intervention scenario	Comparison scenario	p-value
Simulated patient-months (baseline period)	720	720	—
Mean age (years)	66.9 ± 9.8	66.6 ± 10.1	0.72
Male (%)	54.1	53.6	0.81
Advanced malignant disease (%)	74.3	73.8	0.84
End-stage non-malignant disease (%)	25.7	26.2	0.84
Baseline opioid dose (OME, mg/day)	62.4 ± 21.6	61.9 ± 22.3	0.68
Moderate-to-severe pain (%)	78.6	79.1	0.77

Note: Values are derived from the simulated baseline dataset generated for policy evaluation. Continuous variables are presented as mean ± SD. OME = oral morphine equivalents. Baseline characteristics were intentionally balanced to satisfy the assumptions of the DiD analytical framework.

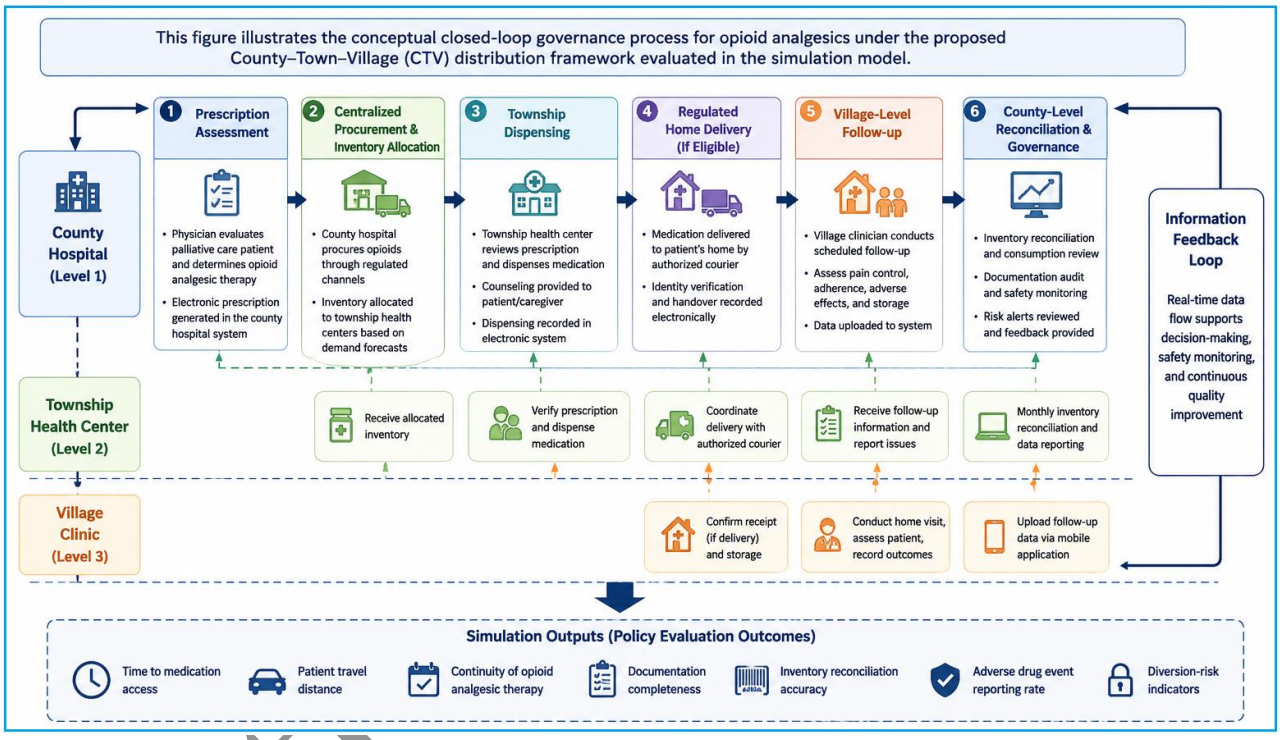


Fig. 2: Conceptual closed-loop pharmaceutical governance framework incorporated into the simulation model. The figure illustrates the coordinated responsibilities of county hospitals, township health centers and village clinics for centralized procurement, prescription governance, opioid dispensing, regulated home delivery, follow-up monitoring, electronic traceability and inventory reconciliation within the proposed CTV pharmaceutical distribution framework.

Mean monthly travel distance required to obtain opioid analgesics decreased from 38.2 km during the baseline period to 12.4 km after simulated implementation in the intervention scenario. By comparison, only a marginal reduction was observed in the conventional distribution scenario (36.9 km to 35.8 km).

The estimated DiD effect corresponded to a projected reduction of 24.9 km per patient-month (95% CI: −28.7 to −21.1; $p < 0.001$), reflecting the combined contribution of township-level dispensing services and regulated home delivery incorporated within the conceptual pharmaceutical governance model. Figure 4 illustrates the projected changes in patient travel distance associated with the simulated implementation of the three-level pharmaceutical distribution framework.

- ***Continuity of opioid analgesic therapy***: The simulation projected a substantial improvement in the continuity of opioid analgesic therapy following implementation of the proposed CTV pharmaceutical distribution framework. In the intervention scenario, the proportion of days covered by dispensed opioid medication increased from 70.8% during the baseline period to 84.9% following simulated implementation. In contrast, the comparison scenario demonstrated only a modest improvement from 71.2% to 72.6% over the corresponding observation period (Table 2).

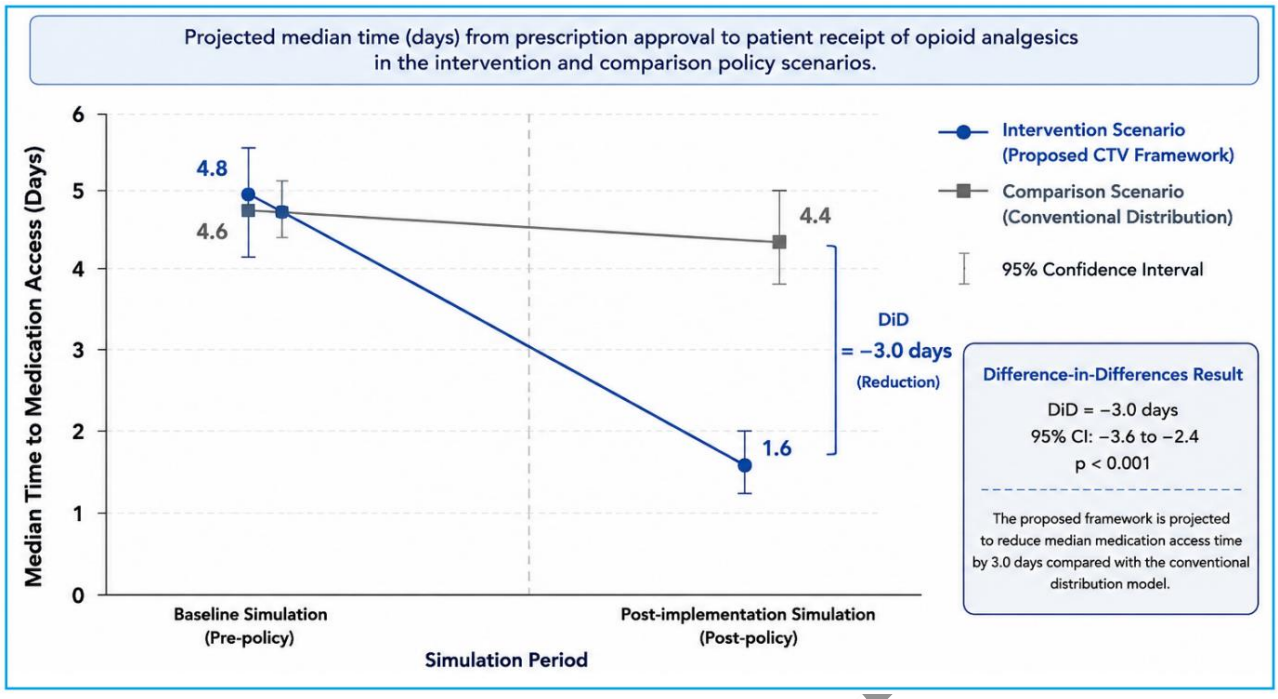


Fig. 3: Projected DiD trends in median medication access time before and after simulated implementation of the proposed CTV pharmaceutical distribution framework.

Table 2: Projected effects of the proposed CTV pharmaceutical distribution framework on medication accessibility and continuity of opioid therapy.

Outcome	Policy scenario	Baseline	Post-implementation	DiD estimate (95% CI)	p-value
Time to medication access (days, median)	Intervention	4.8	1.6	−3.0 (−3.6, −2.4)	<0.001
	Comparison	4.6	4.4	—	—
Travel distance (km per patient-month)	Intervention	38.2	12.4	−24.9 (−28.7, −21.1)	<0.001
	Comparison	36.9	35.8	—	—
Continuity of opioid therapy (%)	Intervention	70.8	84.9	+12.7 (8.9, 16.5)	<0.001
	Comparison	71.2	72.6	—	—

Note: Estimates represent projected policy effects generated by the simulation model. CI are two-sided at the 95% level. Statistical significance was defined as $p < 0.05$.

DiD analysis estimated a projected improvement of 12.7 percentage points in treatment continuity (95% CI: 8.9–16.5; $p < 0.001$), suggesting that decentralized medication dispensing, regulated home delivery and coordinated village-level follow-up collectively reduced interruptions in opioid therapy within the simulated policy environment.

Figure 5 illustrates the projected trends in continuity of opioid analgesic therapy before and after simulated implementation of the proposed pharmaceutical distribution framework, demonstrating a substantially greater improvement in the intervention scenario than in the conventional county hospital-based distribution model.

Pharmaceutical governance and medication safety

The proposed pharmaceutical governance framework was projected to substantially improve documentation quality and medication management across the simulated county-level medical consortia. Documentation completeness throughout the closed-loop pharmaceutical management process increased from 61.3% during the baseline period to 88.9% following simulated implementation in the intervention scenario, whereas only minimal improvement was observed in the comparison scenario. DiD analysis indicated that the proposed governance framework substantially enhanced the completeness of prescribing, dispensing, delivery and follow-up documentation (Table 3). Similarly, projected inventory reconciliation accuracy improved to 98.0% under the intervention scenario compared with 93.4% in the conventional distribution scenario ($p = 0.004$), reflecting strengthened pharmaceutical governance through centralized inventory management, standardized documentation procedures and continuous electronic traceability.

Article in Press

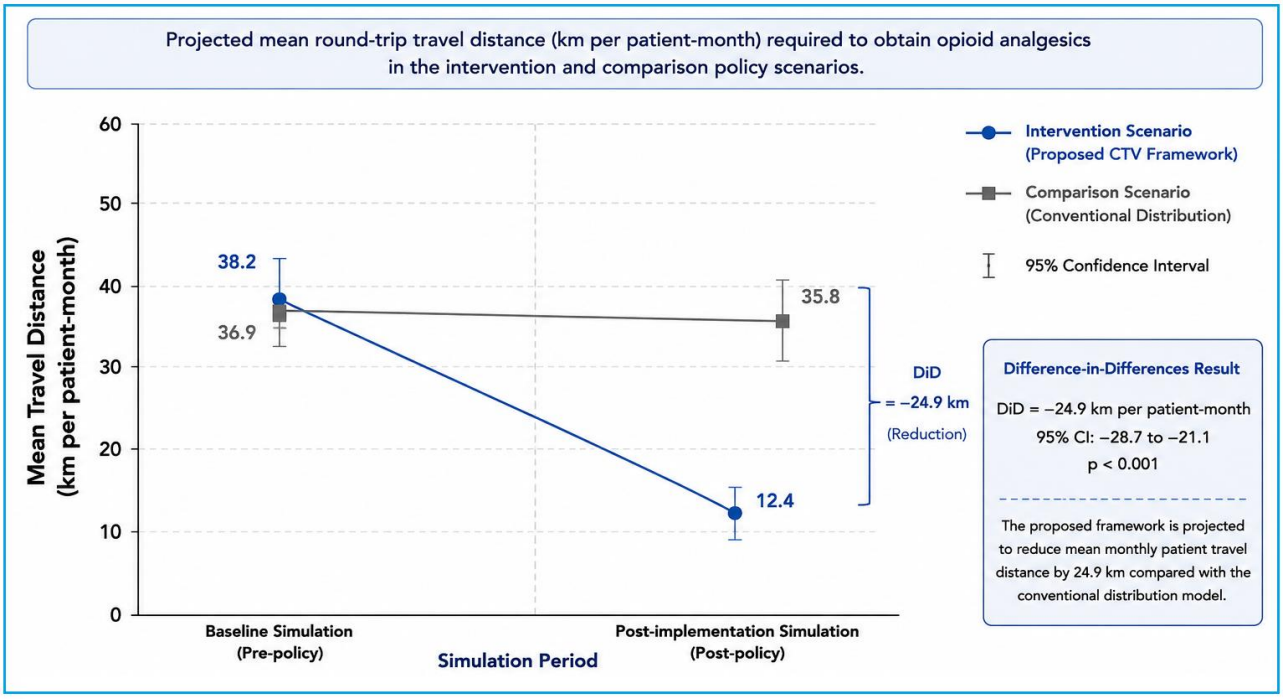


Fig. 4: Projected changes in mean monthly patient travel distance associated with simulated implementation of the proposed CTV pharmaceutical distribution framework.

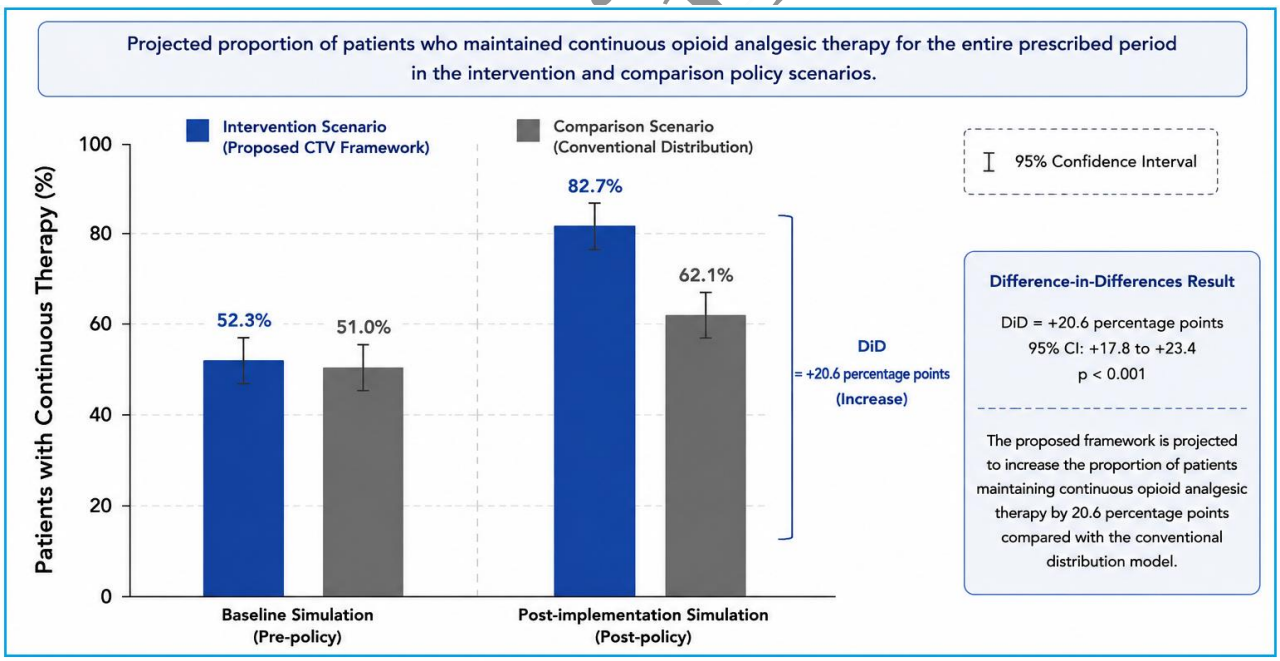


Fig. 5: Projected continuity of opioid analgesic therapy before and after simulated implementation of the proposed CTV pharmaceutical distribution framework in the intervention and comparison policy scenarios.

The projected rate of documented adverse drug events increased from 5.9 to 8.4 reports per 100 patient-months following simulated implementation ($p = 0.012$). This increase was interpreted as improved pharmacovigilance resulting from enhanced medication monitoring, standardized documentation and coordinated follow-up conducted by township health centers and village clinics rather than an increase in the true incidence of adverse drug reactions.

Importantly, expansion of medication accessibility did not increase projected diversion risk.

Table 3: Projected pharmaceutical governance and medication safety outcomes following simulated implementation of the CTV pharmaceutical distribution framework.

Indicator	Intervention scenario	Comparison scenario	p-value
Documentation completeness (%)	88.9	65.0	<0.001
Inventory reconciliation accuracy (%)	98.0	93.4	0.004
Documented adverse drug event reports (per 100 patient-months)	8.4	6.3	0.012
Diversion-risk indicators (%)	1.8	1.9	0.74

Note: Values represent projected simulation outcomes following implementation of the proposed pharmaceutical distribution framework. Higher adverse drug event reporting reflects improved detection and monitoring rather than increased medication-related harm, while diversion-risk indicators represent predefined governance alerts rather than confirmed diversion events.

Table 4: Comparison of projected operational performance indicators between the intervention and comparison scenarios.

Indicator	Intervention	Comparison
Township health centers meeting dispensing authorization criteria (%)	83.3	N/A
Pharmacy personnel completing standardized certification (%)	92.0	N/A
Median delivery lead time (hours)	18.2	N/A
Deliveries with complete identity verification (%)	99.1	N/A
Monthly inventory reconciliation completed on schedule (%)	98.5	93.4

Note: Values represent projected operational performance generated by the simulation model. In the comparison scenario, decentralized township dispensing and regulated home delivery were not implemented; therefore, some indicators are not applicable (N/A).

Diversion-risk indicators remained comparable between the intervention and comparison scenarios (1.8% vs. 1.9%; $p = 0.74$), suggesting that improved access to opioid analgesics could be achieved without compromising medication security when supported by standardized pharmaceutical governance, electronic traceability and routine auditing procedures.

Collectively, the simulation findings indicate that implementation of the proposed CTV pharmaceutical distribution framework has the potential to improve multiple dimensions of opioid medication management. In addition to enhancing medication accessibility and treatment continuity, the model projected improvements in pharmaceutical governance, documentation quality, inventory control and pharmacovigilance without increasing indicators of medication diversion. These findings support the feasibility of the proposed governance framework as a policy model for future prospective evaluation in county-level healthcare systems.

Projected operational performance of the CTV pharmaceutical distribution framework

The simulation projected a high level of operational feasibility for implementation of the proposed CTV pharmaceutical distribution framework within county-level medical consortia. Under the simulated intervention scenario, approximately 83.3% of modeled township health centers satisfied the predefined requirements for authorization to dispense opioid analgesics, including secure medication storage, standardized dispensing procedures, trained pharmacy personnel and electronic documentation capabilities.

The simulation further projected that 92.0% of pharmacy personnel would successfully complete standardized pharmaceutical governance training before implementation of decentralized dispensing services. Compliance with identity verification procedures during regulated home delivery remained consistently high, with full verification projected for 99.1% of medication deliveries. The median projected delivery lead time from prescription approval to patient receipt was 18.2 hours, reflecting the operational efficiency of the proposed coordinated distribution model.

Inventory reconciliation also demonstrated excellent projected performance, with 98.5% of monthly reconciliation procedures completed according to predefined pharmaceutical governance standards. Collectively, these findings suggest that the proposed governance framework could be implemented with a high degree of operational consistency while maintaining regulatory oversight of controlled medicines (Table 4).

Sensitivity analysis results

Deterministic sensitivity analyses were performed to evaluate the robustness of the projected policy effects under alternative operational assumptions. Simulation parameters, including patient volume (±20%), medication demand (±15%), travel distance (±20%), documentation compliance (±15%) and adverse drug event reporting rates (±20%), were systematically varied while maintaining the same analytical framework.

Article in Press

Across all evaluated scenarios, the proposed CTV pharmaceutical distribution framework consistently demonstrated shorter projected medication access times, reduced patient travel distance, improved continuity of opioid therapy and higher documentation completeness compared with the conventional county hospital-based distribution model. Although the magnitude of the projected effects varied slightly across simulation scenarios, the direction and statistical significance of the principal findings remained unchanged.

Additional scenario analyses incorporating reduced township dispensing capacity, delayed medication transportation and lower eligibility for regulated home delivery similarly demonstrated stable performance of the proposed pharmaceutical governance framework. These findings indicate that the projected benefits of the intervention were robust across a range of clinically and operationally plausible assumptions, supporting the internal consistency of the simulation model.

DISCUSSION

This simulation-based policy-modeling study evaluated the potential operational performance of a proposed CTV pharmaceutical distribution framework for opioid analgesics within county-level medical consortia, using Zhejiang Province as a conceptual policy context (Bowra *et al*., 2024). Unlike previous studies that primarily describe existing pharmaceutical distribution practices or evaluate isolated interventions, the present work developed and assessed a comprehensive pharmaceutical governance framework integrating centralized county-level oversight, township-level dispensing, regulated home delivery and village-level follow-up within a closed-loop medication management system. The simulation findings suggest that such an integrated governance model has the potential to improve medication accessibility, strengthen pharmaceutical governance and enhance continuity of opioid therapy while maintaining appropriate regulatory control over controlled medicines (Alford *et al*., 2025).

One of the principal projected benefits of the proposed framework was improved medication accessibility. The simulation estimated that decentralizing opioid dispensing to qualified township health centers, together with regulated home delivery for eligible patients, could reduce median medication access time by approximately three days while substantially decreasing patient travel distance. Although these findings are based on simulated policy scenarios, they are consistent with previous studies showing that decentralized pharmaceutical services and community-based medication delivery can reduce geographical barriers to healthcare, particularly in rural populations with limited mobility (Clark *et al*., 2023; Lizano-Diez *et al*., 2022). For patients receiving palliative care, reducing travel burden may facilitate more timely access to opioid analgesics and improve healthcare delivery efficiency.

Another major result of the current study is the expected enhancement in opioid analgesic therapy continuity. To achieve effective symptom control in palliative care settings, patients must have continuous access to prescribed opioid medication; interruptions of treatment may result in breakthrough pain, unnecessary emergency healthcare utilization and deterioration in quality of life (Prajapati *et al*., 2025). Model-directed changes through the simulation included increased access, coordinated medication dispensing and regulation of home delivery with follow-up at the village level, rather than modifications to prescribing practice, thereby contributing to improved treatment continuity. This finding suggests that enhancing organizational capacity of pharmaceutical services could improve continuity of care without needing to change clinical treatment guidelines or prescribing authority.

An important contribution of this study is its emphasis on pharmaceutical governance rather than pharmaceutical distribution alone. The proposed framework extends beyond redistribution of dispensing responsibilities by integrating centralized procurement, inventory management, prescription governance, standardized documentation, electronic traceability and multidisciplinary monitoring into a unified governance structure.

The projected improvements in documentation completeness and inventory reconciliation suggest that decentralizing dispensing services does not necessarily weaken regulatory oversight when supported by standardized governance procedures and continuous electronic monitoring. These findings are consistent with contemporary pharmaceutical policy literature indicating that medication safety depends more on governance quality, documentation standards and traceability mechanisms than on the physical location where medicines are dispensed (Di Gaudio *et al*., 2024; Van Ornum and Wilson, 2025).

The simulation also projected better pharmacovigilance because no evidence of an increased risk of diversion was identified. The greater number of recorded adverse drug events noted in the intervention scenario is largely likely a reflection of better detection and reporting due to coordinated monitoring at the township level with follow-up done at the village level rather than representing an actual increase in medication-related harm incidence. That interpretation is supported by the stable diversion-risk proxies found across both policy scenarios. Taken together, these data suggest that pharmaceutical governance enhancements may improve access to medications, documentation quality and safety surveillance without

Article in Press

sacrificing regulatory control over opioid analgesics. These observations reflect international guidance for balanced policies to open up legal access to controlled medicines while strengthening monitoring and accountability systems (Coste *et al*., 2023).

From a health policy perspective, the proposed pharmaceutical governance framework provides a conceptual approach to strengthening medication management within county-level medical consortia. Rather than introducing a new healthcare organizational structure, it builds on the existing CTV healthcare network by defining standardized governance responsibilities at each administrative level (Abadie *et al*., 2025).

Under the framework, county hospitals serve as centralized pharmaceutical governance units responsible for procurement, inventory control, prescribing oversight and auditing; township health centers provide regulated dispensing and clinical monitoring; and village clinics deliver structured follow-up, adherence support, patient education and early identification of medication-related concerns. This coordinated approach aligns with broader healthcare system goals of strengthening primary healthcare, improving equitable access to essential medicines and enhancing continuity of pharmaceutical care within integrated service networks (Kok *et al*., 2025).
From a healthcare governance perspective, the proposed pharmaceutical governance framework provides a conceptual approach to strengthening medication management within county-level medical consortia. Rather than introducing a new healthcare organizational structure, it builds on the existing CTV healthcare network by establishing standardized governance responsibilities at each administrative level (Balikubiri *et al*., 2025).

Within this framework, county hospitals serve as centralized pharmaceutical governance units responsible for procurement, inventory control, prescribing oversight and auditing; township health centers provide regulated dispensing and clinical monitoring; and village clinics support structured follow-up, medication adherence, patient education and early identification of medication-related concerns (Kok *et al*., 2025). This coordinated model aligns with broader healthcare objectives of strengthening primary healthcare, improving equitable access to essential medicines and enhancing continuity of pharmaceutical care across integrated service networks (Ali Thorakkattil *et al*., 2024).

At the health system level,, the proposed pharmaceutical governance framework provides a conceptual approach to strengthening medication management within county-level medical consortia. Rather than introducing a new healthcare organizational structure, it builds on the existing CTV healthcare network by defining standardized governance responsibilities at each administrative level (Shen *et al*., 2024).

Under this framework, county hospitals serve as centralized pharmaceutical governance units responsible for procurement, inventory control, prescribing oversight and auditing; township health centers provide regulated dispensing and clinical monitoring; and village clinics deliver structured follow-up, adherence support, patient education and early identification of medication-related concerns (Balikubiri *et al*., 2025). Together, these coordinated roles support broader healthcare objectives of strengthening primary healthcare, improving equitable access to essential medicines and enhancing continuity of pharmaceutical care across integrated service networks (Osyntseva, 2025).

The conceptual framework assessed within this research might also hold wider implications beyond the case of Zhejiang Province. While the governance principles underlying the proposed model—which include centralized oversight, decentralized medication access, closed-loop traceability, multidisciplinary coordination and standardized documentation—may be transferable to any region with a wish to advance access to essential controlled medicines, healthcare systems differ greatly in their regulatory requirements for drug imports and distribution, workforce capacity (understanding of task-delegation models), digital infrastructure and pharmaceutical legislation. However, successful implementation in a variety of health care settings may rely on integration with local regulatory environments and availability of resources and infrastructure provided at a national level (Conduah *et al*., 2025; Belrhiti *et al*., 2024).

Study limitations

In interpreting the findings of this study, several limitations need to be taken into account. The study was designed as a simulation-based policy-modeling rather than an empirical implementation investigation. Thus, all reported outcomes are hypothetical impacts produced by preset operational assumptions and should not be considered direct measures of clinical efficacy or real health systems performance (Levin *et al*., 2025). While the simulation modeled complex healthcare processes that were based on peer-reviewed literature, FDA regulations from published reports and unique county-level healthcare factors, real-world implementation may be affected by additional organization-specific regulatory requirements as well as an economic climate or culture that impact full adoption and clinical delivery but were not explicitly represented in the model (Garber and Okhrin, 2026).

Second, the current simulation further assumed that all modeled county- level medical consortia implement uniform governance procedures for their pharmaceutical choices. The workforce capacity, pharmacy infrastructure, digital information systems, regulatory compliance and institutional resources may result in heterogeneity of implementation fidelity, which can then have downstream

Article in Press

effects on operational performance within the context of routine healthcare practice. Thus, future studies should assess the proposed framework in various healthcare environments to validate its flexibility and generalizability (Glasgow *et al*., 2024).

Third, the simulation focused on health system performance and pharmaceutical governance rather than patient outcomes. Although the anticipated benefits of improved medication accessibility and treatment continuity may contribute to better palliative care, patient-reported pain control, quality of life, caregiver burden, medication adherence, healthcare utilization, and economic outcomes were not directly assessed in this study. But these clinically relevant endpoints should be included in future prospective implementation studies (Lee *et al*., 2025). Finally, the conceptual framework was evaluated using Zhejiang Province as a representative policy context because of its county-level healthcare structure and rural service characteristics. Although the governance principles proposed in this study may be applicable to other healthcare systems, successful implementation elsewhere would require adaptation to local legislation governing controlled medicines, healthcare financing mechanisms, workforce availability, pharmaceutical infrastructure and digital health capabilities. Consequently, external validity should be established through prospective multicenter implementation studies before broader policy adoption is considered (Wojcik *et al*., 2025).

Despite these limitations, the present study provides a structured proof of concept demonstrating how simulation-based policy modeling can be used to evaluate innovative pharmaceutical governance strategies before large-scale implementation. By identifying potential operational benefits, governance challenges and implementation requirements in a simulated environment, the framework offers a practical foundation for future empirical research and evidence-informed pharmaceutical policy development.

CONCLUSION

This simulation-based policy-modeling study developed and evaluated a conceptual CTV pharmaceutical distribution framework designed to improve access to opioid analgesics for palliative care within county-level medical consortia. The simulation projected that integrating centralized pharmaceutical governance with decentralized township-level dispensing, regulated home delivery and structured village-level follow-up may improve medication accessibility, reduce patient travel burden, enhance continuity of opioid therapy, strengthen pharmaceutical governance and support medication safety while maintaining regulatory oversight of controlled medicines.

Rather than proposing a new healthcare organizational structure, the study demonstrates the potential value of strengthening pharmaceutical governance within the existing CTV healthcare network through standardized operational procedures, electronic traceability, multidisciplinary coordination and closed-loop medication management. These governance principles may provide a useful conceptual framework for future pharmaceutical policy development in rural and resource-constrained healthcare systems seeking to improve equitable access to essential controlled medicines.

Since the results are based on modeled policy scenarios, they can be interpreted as forecasts and should not be considered proof of real-world impact. Future prospective implementation studies conducted within real-world healthcare organizational structures with multidisciplinary involvement of frontline providers and patients are necessary to test the hypothesized operational, clinical, economic, legislative and regulatory impact of the proposed framework. Implementation feasibility, cost-effectiveness, patient-reported outcomes and long-term sustainability across diverse health care settings should be assessed before widespread implementation.

Acknowledgments
None.

Authors' contributions
Hongwu Wang: Conceptualized the study, designed the methodology and drafted the manuscript; Caiying Zhang: Contributed to data collection, analysis and manuscript revision; Ting Zhu: Supervised the project, provided clinical guidance and critically revised the manuscript. All authors reviewed and approved the final version.

Funding
This work was supported by the Science and Technology Program Project of Medicine and Health of Zhejiang Province (No.2023XY173), Zhejiang Provincial Conba Hospital Management Soft Science Research Project (No.2023ZHA-KEB321).

Data availability statement
The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Ethical approval
Not applicable. This study involved exclusively simulated data and did not include human participants or identifiable patient information.

Conflict of interest
The authors declare no conflict of interest.

Article in press

REFERENCES

Abadie C, Abderrahmane A, Abdous O, Abel C, Ackermann O, Acquaviva C, Ader F, Adham S, Adjaoud D, Afenjar A and Aladjidi N (2025). PFMG2025–integrating genomic medicine into the national healthcare system in France. *Lancet Reg. Health Eur.*, **50**:50.

Ahmed R and Tamim TR (2025). Enhancing medication safety: The role of community and hospital pharmacists in modern healthcare systems. *Radinka J. Health Sci.*, **2**(3): 328–355.

Aiken AR, Starling JE, Scott JG and Gomperts R (2022). Requests for self-managed medication abortion provided using online telemedicine in 30 US states before and the Dobbs v. Jackson Women's Health Organization decision. *JAMA*, **328**(17): 1768–1770.

Alford AS, Moreno HL, Benjamin MM, Dickinson CF and Hamann MT (2025). Exploring the therapeutic potential of mitragynine and corynoxeine: Kratom-derived indole and oxindole alkaloids for pain management. *Pharmaceuticals*, **18**(2): 222.

Ali D, de Castro R, Ehsani R, Vougioukas S and Wei P (2025). Unlocking the potential of electric and hybrid tractors via sensitivity and techno-economic analysis. *Appl. Energy*, **377**:124545.

Ali Thorakkattil S, Madathil H, Abideen Parakkal S, Ikram Arain S, Hamad AlDobayan Z, Abbas Abu Shoumi F, Jabbour RS, Mansour Fallatah A, Mohammed Ageeli M and Humaidi AlHarbi S (2024). Advancements in ambulatory care pharmacy practice in Saudi Arabia: A comprehensive review of innovations and best practices at Johns Hopkins Aramco Healthcare. *Saudi Pharm. J.*, **32**(10):1-9.

Al-Worafi YM (2023). Medicine availability and affordability in developing countries. In: Handbook of Medical and Health Sciences in Developing Countries. Cham: Springer, pp. 1–29.

An K, Zhang J, Wang X, She Y and Li S (2025). Integration and innovation: Medical and health consortia improving continuing medical education in China. *Front. Public Health*, **13**: 1633363.

Anand A, Mammen MV, Suman A, Kumar A, Mustaffa M and Gill L (2025). Bridging health and governance: The role of pharmacies in local systems. *Lex Localis*, **23**(S5): 401–413.

Andiç-Mortan E and Gonul Kochan C (2023). Modeling a closed-loop vaccine supply chain with transshipments to minimize wastage and threats to the public: A system dynamics approach. *J. Humanit. Logist. Supply Chain Manag.*, **13**(2): 216–234.

Asperti F, Foglia E, Pirovano G, Pozzi R, Rossi T, Punginelli M and Schettini F (2024). Redesigning the drugs distribution network: The case of the Italian national healthcare service. *Systems*, **12**(2): 56.

Balikubiri H, Kemp-Casey A andrade AQ and Roughead EE (2025). Elements of healthcare delivery required to facilitate the clinical governance of hospital pharmacy services: A document review. *Health Res. Policy Syst.*, **23**(1): 100.

Belrhiti Z, Bigdeli M, Lakhal A, Kaoutar D, Zbiri S and Belabbes S (2024). Unravelling collaborative governance dynamics within healthcare networks: A scoping review. *Health Policy Plan.*, **39**(4):412-428.

Bowra A, Perez-Brumer A, Forman L and Kohler JC (2024). Interconnected influence: Unraveling Purdue pharmaceutical's role in the global response to the opioid crisis. *Int. J. Drug Policy*, **133**:104604.

Carbonara L, Casale G, De Marinis MG, Bosetti C, Valle A, Carinci P, D'Andrea MR and Corli O (2025). Adherence to ESMO guidelines on cancer pain management and their applicability to specialist palliative care centers. *Pain Pract.*, **25**(1): e13418.

Cha J, Cha ED, Yoo EH and Song H (2025). Modeling ROI in chronic disease management: A simulation-based framework integrating patient adherence and policy timing. *BMC Public Health*, **25**(1): 4270.

Chen Q, Newton R and Griffin P (2025). Fair allocation strategies for opioid settlements. *Health Care Manag. Sci.*, **28**(3): 335–356.

Chu M, Zhang S, Gong J, Yang S, Yang G, Sun X, Wu D, Xia Y, Jiao J, Peng X and Peng Z (2025). Telemedicine-based integrated management of atrial fibrillation in village clinics. *Nat. Med.*, **31**(4): 1276–1285.

Clark J, Salins N, Daniel S, Currow DC, Jones L, Pearson M, Bunton R, Mankel J, Braithwaite C, Gilchrist MM and Johnson MJ (2023). Views and experiences of opioid access amongst palliative care providers. *PLOS Glob. Public Health*, **3**(9): e0002401.

Coghlan R, Shamieh O and Bloomer MJ (2022). Inequities of palliative care availability and access to opioids in low- and middle-income countries. *Palliat. Med.*, **36**(3): NP1–NP2.

Coluzzi F, Scerpa MS, Rocco M and Fornasari D (2022). The impact of P-glycoprotein on opioid analgesics. *Int. J. Mol. Sci.*, **23**(22): 14125.

Conduah AK, Ofoe S and Siaw-Marfo D (2025). Data privacy in healthcare: Global challenges and solutions. *Digit. Health*, **11**:20552076251343959.

Correia de Matos R, do Nascimento G and Campos Fernandes A (2025). Integrated care models and their impact. *J. Integr. Care*, **33**(1): 63–74.

Crosland P, Ho N, Hosseini SH, Vacher C, Skinner A, Natsky AN, Rosenberg S, Hasudungan R, Huntley S, Song YJ and Lee GY (2024). Cost-effectiveness of system-level mental health strategies for young people in the Australian capital territory: A dynamic simulation modelling study. *Lancet Psychiatry*, **11**(2): 123-133.

Coste A, Wong A, Bokern M, Bate A and Douglas IJ (2023). Methods for drug safety signal detection. *Pharmacoepidemiol. Drug Saf.*, **32**(1): 28–43.

Demir E, Yakutcan U and Page S (2024). Using simulation modelling to transform hospital planning and

Article in Press

management to address health inequalities. *Soc. Sci. Med.*, **347**: 116786.

Desai M (2022). Pharmacovigilance and spontaneous adverse drug reaction reporting. *Perspect. Clin. Res.*, **13**(4): 177–179.

Di Gaudio F, Giaccone V, Cucina A, Indelicato S, Raso M, Brunacci G, Lundari A, Rotolo MC, Busardo F and La Rocca M (2024). External quality assessment systems for psychoactive substances. *J. Pharm. Biomed. Anal.*, **245**: 116175.

Eason BE, Vest TA, Mieure KD, Neal D and Tryon J (2023). Evaluation of controlled substances management. *J. Pharm. Pract.*, **36**(1): 96–103.

Fan Y, Ye Z, Jiang M, Jing L, Zhang H, Tang Z, Qiao H, Wang X, Zhang X, Tang Y and Liu L (2026). Opioid consumption and policy alignment in China. *Support. Care Cancer*, **34**(3): 272.

Feng Z, Liu X, Zhao Y and Huang Z (2024). Evolutionary game model and simulation analysis of multi-stakeholder behaviour for promoting Braille labelling on pharmaceutical packaging in China's legal framework. *Humanit. Soc. Sci. Commun.*, **11**(1):1-6.

Feng Z, Ye Y, Ye H and Tang Z (2022). Changes in pharmaceutical retail market and inequality. *BMJ Open*, **12**(11): e063739.

Fanda RB, Probandari A, Kok MO and Bal RA (2025). Managing medicines in decentralization. *Health Policy Plan.*, **40**(3): 346–357.

Gao H, Du XL, Liao JZ and Xiang L (2022). The pathway of China's integrated delivery system. *Curr. Med. Sci.*, **42**(6): 1164–1171.

Garber S and Okhrin Y (2026). Machine learning for intensive care unit length-of-stay prediction: A simulation-based approach to bed capacity management. *Med. Decis. Making*, **46**(3): 355-370.

Glasgow RE, Trinkley KE, Ford B and Rabin BA (2024). The application and evolution of the practical, robust implementation and sustainability model (PRISM): history and innovations. *Glob. Implement. Res. Appl.*, **4**(4): 404-420.

Hemmeda L, Koko AE, Mohamed RF, Mohammed YI, Elabid AO, Omer AT, Hamida AA, Haiba AM, Ali EM, Abdelgadir II and Al Fanob RM (2023). Accessibility crisis of essential medicines. *Int. J. Equity Health*, **22**(1): 216.

Jackson JR, Harle CA, Silverman R, Simon K and Menachemi N (2022). State-level regulations and opioid outcomes. *Drug Alcohol Depend.*, **232**: 109294.

Jaffe K, Gagnon J, Harding L, Carvajal J, Jamieson DW, MacDonald S, Foreman J and Oviedo-Joekes E (2024). Accessible care and opioid agonist treatment. *Can. J. Disabil. Stud.*, **13**(3): 168–193.

Kim DD (2024). Simulation modelling in public health policy. *Lancet Public Health*, **9**(3): e150–e151.

Knaul FM, Arreola-Ornelas H, Kwete XJ, Bhadelia A, Berterame S, Connor SR, De Lima L, Downing J, Krakauer EL, Mendez-Carniado O and Pastrana T (2025). Distributed opioids in morphine equivalents. *J. Pain Symptom Manage.*, **69**(2): 204–215.

Khan Z, Karatas Y and Hamid SM (2023). Pharmacovigilance knowledge and barriers. *PLoS One*, **18**(5): e0285811.

Kok MO, Fanda RB, Lubbers RU, van Gurp M, Ravinetto R and Probandari A (2025). Assessing the performance of local pharmaceutical systems: An analytical approach to improve access to medicine. *J. Med. Access*, **9**: 27550834251371502.

Lee MJ, Baker DM, Hawkins D, Blackwell S, Arnott R, Harji D, Thorpe G, Chapman SJ and Jones GL (2025). Development of a patient-reported outcome measure for gastrointestinal recovery after surgery (PRO-diGI). *Br. J. Surg.*, **112**(4): znaf055.

Levin C, Suliman M, Naimi E and Saban M (2025). Augmenting intensive care unit nursing practice with generative AI: A formative study of diagnostic synergies using simulation-based clinical cases. *J. Clin. Nurs.*, **34**(7): 2898-2907.

Lizano-Díez I, Amaral-Rohter S, Perez-Carbonell L and Aceituno S (2022). Impact of home care services. *Home Health Care Manag. Pract.*, **34**(2): 148–162.

Liu H, Ma C, Yang Y, Liao W and Wang Y (2025). Enhancing PHC accessibility. *BMC Health Serv. Res.*, **25**(1): 973.

Lo UC, Musa H, Li J, Gaon J, Hibbs DE and Ong JA (2024). Medication hesitancy in palliative care. *Palliat. Support. Care*, **22**(3): 610–622.

Marcus HJ, Ramirez PT, Khan DZ, Layard Horsfall H, Hanrahan JG, Williams SC, Beard DJ, Bhat R, Catchpole K, Cook A and Hutchison K (2024). The IDEAL framework for surgical robotics: Development, comparative evaluation and long-term monitoring. *Nat. Med.*, **30**(1): 61-75.

Natali D, Pavolini E and Terlizzi A (2023). Multi-level governance in healthcare. *Politics Gov.*, **11**(4): 365–377.

Noto G, De Domenico F, Buttigieg SC and Barresi G (2025). Managing and measuring performance of health prevention services: A simulation-based approach. *J. Health Organ. Manag.*, **39**(9): 305-324.

Osyntseva A (2025). Current trends in tuberculosis pharmacotherapy: Availability of essential medicines. *SSP Mod. Pharm. Med.*, **5**(2): 1-4.

Oyri SF and Wiig S (2022). Linking resilience and regulation in healthcare. *BMC Health Serv. Res.*, **22**(1): 510.

Pei Y, Qi X, Zhou Z, Lou Y, Wang J, Li Y and Wu B (2026). Pain prevalence and management in China. *J. Gerontol. A*, **81**(3): glaf282.

Pham H, Ober A, Baldwin LM, Mooney LJ, Zhu Y, Fei Z and Hser YI (2024). Social determinants and opioid treatment continuity. *J. Addict. Med.*, **18**(3): 331–334.

Rana A and Ram K (2026). Framework for next-generation opioid regulation. *Ther. Innov. Regul. Sci.*, **60**(1): 63–74.

Article in Press

Ramachandran S, Salkar M, Bhattacharya K, Bentley JP, Maharjan S, Eriator I, McGwin G, Mauney MJ and Yang Y (2023). Continuity of opioid prescribing. *Am. J. Manag. Care*, **29**(2): 88–94.

Sanjuda SK, Nagabhushanan T, Sukanya R and Ramya G (2022). Regulatory requirements for controlled drugs. *World J. Pharm. Pharm. Sci.*, **8**(4): 2105–2115.

Shakya S and Ruseski JE (2023). Effects of prescription drug monitoring programs. *Contemp. Econ. Policy*, **41**(3): 435–454.

Shannon K, Shyh G, Ippoliti C, Li H, Kubin C, Stettner S, Mazur S and Dupart P (2026). Decentralized pharmacy model implementation. *Am. J. Health Syst. Pharm.*, **83**(5): e213–e219.

Smith AD (2024). Supply chain management practices in hospitals. *Int. J. Serv. Oper. Manag.*, **48**(2): 155–175.

Shen J, Bu F, Ye Z, Zhang M, Ma Q, Yan J and Huang T (2024). Management of drug supply chain information based on "artificial intelligence + vendor managed inventory" in China: Perspective based on a case study. *Front. Pharmacol.*, **15**: 1373642.

Sokolovska Z and Klepikova O (2024). Model simulators as an analytical basis for strategic decision-making by pharmaceutical companies. *Int. J. Knowl. Manag. Stud.*, **15**(4): 515-542.

Sun F (2022). Rurality and opioid prescribing rates. *Soc. Sci. Med.*, **296**: 114788.

Van Ornum M and Wilson M (2025). Centralized monitoring for diversion prevention. *J. Am. Pharm. Assoc.*, **65**(5): 102426.

Vahos J, Rojas-Cortes R, Daza D, Osorio-Florez LC, Macias Saint-Gerons D, Pastrana T, Munoz S, Fitzgerald J, Porras A, Luciani S and Castro JL (2023). Barriers to opioid access in Latin America. *J. Palliat. Med.*, **26**(2): 199–209.

Wang CK, Tsai TH and Lee CH (2024). Regulation of exosomes as biologic medicines. *Clin. Transl. Sci.*, **17**(8): e13904.

Yang J and Mishra A (2025). Diversion in opioid supply chains. *Manuf. Serv. Oper. Manag.*, **27**(3): 679–699.

Ward ZJ, Gaba Q and Atun R (2024). Cancer incidence and survival for 11 cancers in the Commonwealth: A simulation-based modelling study. *Lancet Oncol.*, **25**(9): 1127-1134.

Wojcik Z, Dimitrova V, Warrington L, Velikova G and Absolom K (2025). Using artificial intelligence to predict patient outcomes from patient-reported outcome measures: A scoping review. *Health Qual. Life Outcomes*, **23**(1):37.

Zezai D, van Rensburg AJ, Babatunde GB, Kathree T, Cornick R, Levitt N, Fairall LR and Petersen I (2024). Barriers to strengthening primary health systems. *BMJ Open*, **14**(11): e087451.

Zhang M, Zou K, Liu Z, Liu D, Wang X, Shi Y, Chen Z, Cheng X, Lang B, Li H and Zeng L (2023). Availability of essential medicines in China. *Front. Public Health*, **11**: 1149838.

Zimmerman A and Laitman A (2024). Adverse effects of prescription opioids. *J. Clin. Med.*, **13**(10): 2746.

Zitu MM, Owen D, Manne A, Zhu Y, Binkheder S and Li L (2026). AI for opioid safety surveillance. *J. Clin. Med.*, **15**(4): 1649.

Zhu S, Liu J, Wang Z and Chen S (2025). Regional disparities in public health services in China. *BMC Health Serv. Res.*, **25**(1): 1172.

Article in Press