https://ijhpm.com
Int J Health Policy Manag 2026;15:9232

OPEN ACCESS

doi 10.34172/ijhpm.9232

IJHPM International Journal of Health Policy and Management

Original Article

Centralize or Decentralize? Simulating the Quality and Affordability Impacts of County-Level Healthcare Reorganization in China

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Abstract

Background: Healthcare decentralization may improve access for lower-complexity care, whereas centralization may improve complex-care outcomes, but optimal inpatient service allocation remains uncertain. We developed a county-level inpatient service-reorganization toolkit combining a framework and simulations.

Methods: We operationalized the framework's four pathways as 11 counterfactual allocation scenarios: three decentralization scenarios, comprehensive (A) and conditional (B–C), and eight centralization scenarios, selective (D1–D6) and full (D7–D8). Decentralization scenarios were simulated for chronic obstructive pulmonary disease (COPD), pneumonia, and lung cancer without complex surgery, with inpatient care redistributed within patients' home counties: to any hospital or primary-care facility (A), hospitals only (B), or by clinical complexity (C). Centralization scenarios were simulated for lung cancer involving complex surgery, reallocating care across county boundaries to designated hospitals under separate volume-based and quality-based rules. Hospitals were selected within cities (D1–D2), with selected county hospitals (D3–D4) or hospitals participating in targeted assistance programs (D5–D6) additionally included, or selected province-wide (D7–D8). We applied these scenarios to 2017–2023 Guangdong discharge records using inverse-probability-weighted regression adjustment (IPWRA) to estimate readmission, in-hospital mortality, and total costs under each scenario, assessing reorganization effects by comparing simulated with observed outcomes.

Results: We analyzed 731 148 COPD, 883 273 pneumonia, and 147 158 lung cancer admissions. Under decentralization, A reduced COPD hospitalization costs but increased readmission and mortality; B/C increased costs and mortality. For pneumonia, A–C lowered costs and readmission but raised mortality. For lung cancer without complex surgery, A–C reduced costs but increased readmission and mortality. Under centralization, D1–D6 generally reduced costs with quality trade-offs; D7/D8 reduced readmission (4.71%–5.21% vs. 8.31%–10.41%) and mortality (1.56%–1.83% vs. 6.17%–7.05%) despite higher costs.

Conclusion: The toolkit links allocation rules to projected quality and affordability, enabling policy-makers to compare options and calibrate the degree of centralization or decentralization to local conditions.

Keywords: Reorganization, County-Level Healthcare, Quality of Care, Healthcare Costs, China

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Citation: Zhu Y, Hu W, Zheng EX, Chen S, Huang X, Huang Y. Centralize or decentralize? Simulating the quality and affordability impacts of county-level healthcare reorganization in China. *Int J Health Policy Manag.* 2026;15:9232. doi:10.34172/ijhpm.9232

Article History:
Received: 23 May 2025
Accepted: 15 November 2026
ePublished: 22 November 2026

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Background

Centralization and decentralization are two important approaches to health service planning. Decentralization can improve geographic access by distributing services across a broader facility network, whereas centralization can improve quality by concentrating care among more experienced providers.[1,2] Evidence suggests that routine care is best delivered close to where people live.[3,4] High-complexity care, such as cancer surgery, should be concentrated in a small number of designated centers to improve outcomes.[1,5] However, most evidence supporting these principles comes from high-income settings in Europe and North America. Much less is known about how centralization and decentralization can be combined in low- and middle-income countries. This evidence gap is increasingly important as health system reforms in low- and middle-income countries have moved beyond expanding coverage to improving quality.[3,6] Inpatient care provides a setting for examining this issue. It is resource-intensive, accounts for a large share of health spending,[7] and often requires stronger quality assurance than routine outpatient care.

In China, this issue is reflected in the organization of county-level inpatient care. County hospitals are expected to provide inpatient care for county residents. Counties are administrative units below prefecture-level cities and generally include county towns and surrounding rural areas. However, China does not have mandatory gatekeeping,[8] and many county hospitals have weaker clinical capacity than

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Key Messages

Implications for policy makers

- Decentralization tends to reduce costs for patients with common respiratory conditions, but only modest improvements in clinical outcomes were observed. With respect to complex lung cancer surgery, centralization improved clinical outcomes but increased costs.
- The geographic level of service allocation can be adapted to local health-system structures when designing reorganization strategies. In this study, the county was used as the basic planning unit because, for rural populations in China, it generally represents the lowest level encompassing both hospitals and primary care facilities. The county-, city-, and province-level scenarios illustrate how reorganization can be structured across different geographic levels. Other regions can define equivalent levels according to their own organizational structures, provider capacity, and service requirements, and adjust the degree and geographic scale of decentralization or centralization accordingly.
- The planning toolkit provides a comprehensive workflow that translates reform objectives into allocation rules and scenario designs and uses local administrative data to simulate anticipated clinical and cost outcomes. Other regions can adapt the toolkit to their own policy objectives by selecting outcome measures that reflect local priorities, such as affordability, geographic accessibility, or equity, so that alternative scenarios can be compared against the outcomes most relevant to local decision-making.

Implications for the public

Different types of inpatient services may require different approaches to health service planning and organization. With respect to common respiratory conditions, decentralization may reduce costs but achieved only limited improvements in clinical outcomes. Conversely, complex surgical procedures, such as major lung cancer surgery, are associated with better survival and lower readmission rates when these procedures are centralized in high-level hospitals within a province or state, even if this incurs higher costs. These findings suggest that a one-size-fits-all approach to healthcare reorganization should be avoided. Instead, services should be allocated based on disease complexity, provider capacity, and the need to balance clinical outcomes, costs and patient access.

city hospitals. Many rural residents therefore bypass county-level facilities and seek inpatient care in cities.[9] This pattern can leave county hospitals underused and redirect health insurance reimbursement flows to city hospitals. It may also widen urban–rural disparities in both access to care and service quality.

Against this background, recent reforms in China (Box 1) have introduced county medical alliances and group-based assistance programs.[10,11] These reforms aim to strengthen county-level clinical service capacity and encourage more admissions to be managed within counties. Many regions track progress using the within-county hospitalization rate,[12] defined as the share of residents' hospital admissions that occur within their home county. Efforts to increase this rate are consistent with a decentralization-oriented approach to service allocation. Such efforts can enable more county residents to receive care closer to where they live and help retain more health insurance reimbursement within counties.[13] However, a higher within-county hospitalization rate is not necessarily better. County-level reform should promote local service use without compromising service quality. Some types of inpatient care can be safely provided within counties, whereas others may require greater clinical experience, technical capacity, or supporting services. This highlights the need to reallocate inpatient services through both decentralization and centralization, keeping suitable services within counties while concentrating more complex services in higher-capacity facilities.

Service allocation decisions may reshape patient pathways, resource use, and system workload. These potential effects need to be considered when developing and evaluating alternative allocation scenarios. However, analytical methods for guiding service allocation remain relatively limited. Previous studies have used structural inputs,[14,15] such as the number of beds or the density of physicians, to guide service planning. These indicators are useful for describing available resources, but they serve as indirect proxies of service capacity and quality. To address these gaps, this study developed a conceptual framework for reorganizing county-level inpatient services by combining decentralization and centralization strategies. The former involves retaining routine inpatient services within the county-level healthcare network, while the latter involves concentrating highly complex services in hospitals with high capacity. On the basis of this framework, we designed a set of allocation scenarios and used simulations to estimate their effects on inpatient outcomes, costs, and system workload for county populations. We selected Guangdong province as the empirical case because it shows large disparities in service capacity across cities and between urban and rural areas[16,17] and provides an informative microcosm of capacity disparities across China. The framework and methods developed in this study can be adapted using local data to inform similar service allocation decisions in other regions.

Methods

Conceptual Framework

Experience in high-income countries suggests that centralization is commonly employed for high-risk services, such as complex tumor resection and acute stroke management.[1,5,21] Concentrating these services can support economies of scale and better quality control, but it can also increase travel burdens. Decentralization, by contrast, is more commonly used for high-volume or lower-complexity care delivered by primary care facilities or through programmatic tuberculosis/HIV services. It can improve access and local responsiveness.[2,3] Yet in areas where providers have limited clinical service capacity, decentralization may make it difficult to ensure service quality. Since neither strategy is universally superior, service allocation should balance centralization and decentralization according to local provider capacity.

To apply this balance to county-level inpatient service planning, these broad strategies need to be translated into

Box 1. China's County-Level Service Delivery Reforms and System Context

Definition of Counties

China's administrative system is structured into four levels: provincial; prefecture (city); county/district; and township. In this article, "county" refers to administrative divisions situated under prefecture-level cities (such as Guangzhou). This category includes counties, county-level cities (such as Yiwu), autonomous counties, and similar entities. They have jurisdiction over the county seat and surrounding rural areas (including townships, towns, and villages), which constitute the main organizational and living space for rural residents. Our case study was located in Guangdong province, which comprises 21 prefecture-level cities. Fifteen of these cities administer 57 county jurisdictions (counties, autonomous counties, or county-level cities), while the remaining six cities administer only urban districts. Our simulations were conducted for these 57 county jurisdictions.

Three-Tier Healthcare System

China's health service delivery system is organized as a three-tier network and does not operate under mandatory gatekeeping or referral requirements.[8] The first tier comprises primary healthcare institutions, such as township health centers, community health centers or stations, and village clinics, which provide primary care and essential public health services. County and district hospitals are generally secondary (Tier 2) institutions, while municipal and provincial hospitals are usually tertiary (Tier 3). Tier-2 and Tier-3 hospitals provide more comprehensive and specialized services than primary care facilities.[18] The county-level healthcare system typically consists of a few hospitals as well as numerous township health centers and village clinics.

County Medical Alliances

To promote continuity of service, China has established vertically integrated delivery networks, particularly at the county level. For rural populations, the county generally represents the lowest administrative and service-planning unit that encompasses both hospital care and primary care facilities. A typical county medical community links a county hospital with township health centers and village clinics, all of which operate under unified leadership, budgeting, personnel management, and clinical protocols. In many counties, part of the health insurance budget is also managed at the county network level[19] rather than solely at the municipal level. Recently, most counties have established at least one such delivery network.

Group-Based Assistance Programs

To address the imbalance between the supply and demand of high-quality medical resources and to encourage their allocation to rural areas, many provinces in China (such as the study case) have introduced group-based assistance policies.[11,12] Under these policies, tertiary hospitals at the provincial and municipal levels provide support to multiple county-level hospitals (and, in some cases, district-level hospitals). Supporting hospitals send clinical and managerial staff to recipient hospitals to bolster specialist services, fill key technical gaps, train local staff, and improve hospital management and service delivery systems.

Decentralization in Practice

In recent years, China has introduced healthcare reforms that incorporate elements of decentralization. For instance, the National Basic Public Health Service Program has transferred the provision of preventive and follow-up services (eg, vaccination, chronic disease management and free health checks for older adults) to primary healthcare institutions.[20] Some counties have piloted bundled payment models tied to county medical alliances,[19] which grants them greater discretion over insurance funds in order to strengthen cost control and promote standardized practice. In these reforms, "decentralization" can involve shifting authority, services, and decision-making power from central governance bodies to lower management levels.

In this paper, however, we use the term in a narrower operational sense to refer only to the allocation of services. We did not evaluate the governance arrangements, authority structures, or decision-making processes that might accompany these allocations.

operational planning paths. For disease-specific inpatient services, this requires clarifying where each service should be arranged and what degree of decentralization or centralization is appropriate. Therefore, we developed a two-dimensional conceptual framework. The first dimension is service setting, defined as the organizational level for arranging a service. It indicates the general direction of allocation. Services organized within the county represent decentralization, whereas services centralized across counties represent centralization. The second dimension is provider-side delivery difficulty, which refers to how difficult it is for providers at the relevant service setting to deliver the service safely. It indicates the degree of decentralization or centralization. Combining these two dimensions generates four planning paths: comprehensive decentralization, conditional decentralization, selective centralization, and full centralization (Figure 1). Because provider capacity varies across settings, it was not possible to determine in advance which path would be most appropriate for each county or service. The four paths were therefore treated as alternative scenarios rather than predetermined solutions. Each was operationalized as one or more allocation scenarios and evaluated separately through simulation. The resulting estimates were then compared to assess the potential effects of different planning approaches and inform context-specific decisions.

(1) Comprehensive Decentralization

This path represents a decentralization-oriented allocation strategy in which inpatient services are delivered through the county's own service network. It applies to services that are generally suitable for decentralization based on international service-planning experience, such as common, standardized, and high-volume inpatient care. Under this path, the service is assumed to be safely provided by county hospitals and other local providers with inpatient capacity. The aim is to keep admissions close to patients' residences, maximize local coverage, and retain insurance expenditure within the county.

(2) Conditional Decentralization

This path represents a more selective form of decentralization. It applies to the same general type of services that are suitable for decentralization, but under conditions where local provider

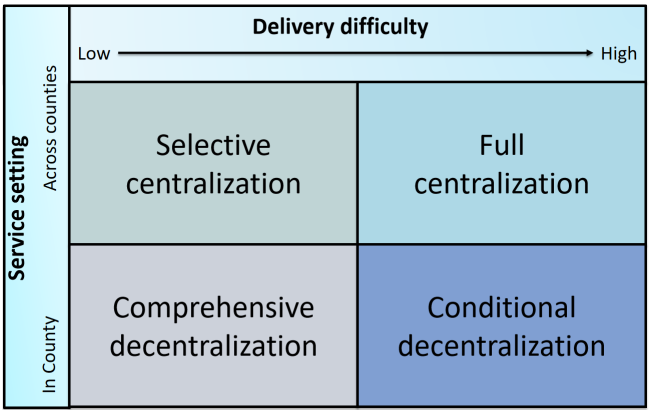


Figure 1. Conceptual Framework for the Replanning of County-level Inpatient Services. Note: In-county care refers to inpatient care provided within the county's own service network, including care provided by county hospitals and primary healthcare institutions. Across-county care refers to inpatient care that is not limited to the patient's own county but may be provided at hospitals located elsewhere within the same city or province.

capacity may be insufficient. In this path, the service remains within the county, but is allocated selectively rather than distributed across all local institutions. Allocation is based on two parallel criteria: provider-side capability and patient-side clinical risk. Provider-side capability limits service delivery to eligible hospitals within the county. Patient-side clinical risk assigns patients according to disease severity, comorbidity burden, or other relevant clinical criteria.

(3) Selective Centralization

This path represents a centralization-oriented allocation strategy in which inpatient services are concentrated in a limited number of designated hospitals within a prefecture-level network. It applies to services that are generally suitable for centralization based on international service-planning experience, such as high-risk, technically demanding, or specialist-dependent inpatient care. Under this path, some counties may not be able to provide a given service safely, but the service can still be supported within the prefecture-level system. The service is therefore no longer delivered separately by each county. Instead, prefecture-level coordination identifies qualified hospitals within the network to provide it. The aim is to concentrate case volume, reduce quality variation across counties, and keep care within a reasonable travel distance.

(4) Full Centralization

This path represents a higher-level form of centralization. It applies to the same general type of services that may be suitable for centralization, but under conditions where the service cannot be reliably supported within prefecture-level networks. Under this path, the service is no longer organized within individual cities or regional networks. Instead, provincial coordination identifies a small number of hospitals to provide it. The aim is to address capacity gaps that cannot be resolved at the prefecture level.

Allocation Scenarios

Using the framework as a blueprint, we constructed 11 allocation scenarios that reflect different ways of implementing the four planning pathways. Scenario A represented comprehensive decentralization; Scenarios B and C represented conditional decentralization; Scenarios D1–D6 represented selective centralization; and Scenarios D7 and D8 represented full centralization. The specifications are reported in Table 1.

We chose three high-burden respiratory conditions (chronic obstructive pulmonary disease [COPD], pneumonia and lung cancer) to represent different levels of care complexity. COPD and pneumonia are common medical conditions with well-established approaches to clinical management,[22,23] whereas lung cancer spans a wider range of treatment complexity, from care that may be provided locally to complex surgery that may require centralization. Accordingly, Scenarios A–C were applied to COPD, pneumonia, and lung cancer admissions without complex surgery, whereas Scenarios D1–D8 were applied to lung cancer admissions involving complex surgery.

Comprehensive Decentralization

Scenario A: Patients are assigned to any hospital or primary healthcare institution in their home county. In this counterfactual scenario, any admissions that would have occurred outside the county are reassigned to the same type within the patient's home county. This ensures that all inpatient care is delivered locally while also considering patients' preferences regarding the type of provider (hospital versus primary healthcare facility).

Conditional Decentralization

Scenario B: Patients are assigned only to county hospitals, reflecting health systems such as those in the UK and Germany[24,25] where primary care facilities generally do not admit inpatients. This approach is intended to clarify the division of roles between hospitals and primary care facilities within the Chinese healthcare system.

Scenario C: Patients are assigned to different healthcare providers in the county according to their clinical needs, including the severity of their condition and the required treatment. This scenario aims to clarify the boundaries of inpatient care between county hospitals and primary healthcare institutions and to ensure that patients' needs align with providers' capability.

Selective Centralization

Based on previous studies,[26,27] service volume and care quality were used as the two main criteria for designating hospitals in the centralization scenarios. Service volume was measured by the number of lung cancer cases, while care quality was assessed using in-hospital mortality and 31-day readmission rates.

Scenario D1: Within each city, hospitals are ranked by cancer service volume, and the top one-third are designated as receiving hospitals. All cancer-service inpatient admissions from that city are reassigned to this designated set.

Scenario D2: Within each city, hospitals are ranked by cancer service quality, and the top one-third are designated as receiving hospitals. All cancer-service inpatient admissions

Table 1. Definition of the 11 Inpatient Service Allocation Scenarios

Planning Pathway	Scenario	Conditions[a]	Services Settings	Allocation Rule
Comprehensive decentralization	A	COPD, pneumonia, and lung cancer without complex surgeries involved	Hospitals or primary healthcare institutions within the county	Patients are admitted to any hospital or primary healthcare institution within their county of residence.
Conditional decentralization	B		Hospitals within county	Inpatient admission is restricted to hospitals within the patient's county of residence.
	C		Hospitals or primary healthcare institutions within the county	Patients with uncomplicated conditions (Charlson Comorbidity Index = 0, nonsurgical, and nonacute) are treated at primary healthcare institutions; all other patients are treated at hospitals.
Selective centralization	D1	Lung cancer with complex surgeries involved	Designated hospitals within each city	All hospitals in each city are ranked by lung cancer service volume (2017–2023). The top one-third are designated as the city's inpatient institutions.
	D2			All hospitals in each city are ranked by the quality of lung cancer care (31-day readmission and in-hospital mortality among lung cancer inpatients, 2017–2023). The top one-third are designated as the city's inpatient institutions.
	D3			In addition to the hospitals designated in Scenario D1, county-level hospitals are ranked province-wide by lung cancer service volume (2017–2023), and the top one-third are designated and assigned to their corresponding city lists based on administrative affiliation.
	D4			In addition to the hospitals designated in Scenario D2, county-level hospitals are ranked province-wide by the quality of lung cancer care (31-day readmission and in-hospital mortality, 2017–2023), and the top one-third are assigned to their corresponding city lists based on administrative affiliation.
	D5			Certain hospitals[b] are assigned by the province to provide targeted assistance to counties. For each city, the hospitals that assist counties under their jurisdiction are added to D1-designated hospitals to form that city's list of designated inpatient institutions.
	D6			Certain hospitals[b] are assigned by province to provide targeted assistance to counties. For each city, the hospitals that assist counties under their jurisdiction are added to the D2-designated hospitals to form that city's list of designated inpatient institutions.
Full centralization	D7		Designated hospitals selected from across the entire province	All hospitals in the province are ranked by lung cancer service volume (2017–2023). The top one-third are designated as province-wide inpatient institutions.
	D8			All hospitals in the province are ranked by the quality of lung cancer care (2017–2023). The top one-third are designated as province-wide inpatient institutions.

Abbreviation: COPD: chronic obstructive pulmonary disease.

Note: [a] We categorized county-level inpatient lung cancer services into two groups on the basis of the surgical classification system used by the three hospitals in Guangdong province with the highest lung cancer service volumes. The first group comprised cases involving high-complexity surgeries (classified as levels 3 and 4), whereas the second group comprised cases involving lower-complexity surgeries (levels 1 and 2) or no surgical intervention. [b] Guangdong province has implemented a group-based assistance policy to strengthen the service capacity of county hospitals. Under this policy, selected provincial- and municipal-level hospitals are designated to provide direct support to county hospitals with the aim of improving clinical capability and overall service delivery.

from that city are reassigned to this designated set.

Scenario D3: Within each city, the designated hospitals from D1 are supplemented by county-level hospitals selected on the basis of a province-wide ranking. Specifically, all county-level hospitals in the province are ranked by cancer service volume, and the top one-third are added to the designated list of the city that administratively governs their county. All cancer-service inpatient admissions from that city are reassigned to this combined set. This scenario was designed to represent a more measured approach to selective centralization. It allows some county-level hospitals with relatively high service volume to remain in the designated network rather than applying a uniformly restrictive concentration strategy.

Scenario D4: Within each city, the designated hospitals from D2 are supplemented by county-level hospitals selected on the basis of a province-wide ranking. Specifically, all county-level hospitals in the province are ranked by cancer service quality, and the top one-third are added to the designated list of the city that administratively governs their county. All cancer-service inpatient admissions from that city are reassigned to this combined set. The rationale for this scenario was similar to that of Scenario D3.

Scenario D5: Within each city, the designated hospitals from D1 are supplemented by hospitals that participate in targeted group-assistance programs supporting counties. All cancer-service inpatient admissions from that city are reassigned to this combined set. This scenario was designed to make selective centralization more compatible with existing service arrangements. At the provincial level, targeted group-assistance arrangements pair county-level hospitals with designated supporting hospitals. These existing collaborative relationships may facilitate patient reallocation and improve the acceptability of service concentration.

Scenario D6: Within each city, the designated hospitals from D2 are supplemented by hospitals that participate in targeted group-assistance programs supporting counties. All cancer-service inpatient admissions from that city are reassigned to this combined set. The rationale for this scenario was similar to that of Scenario D5.

Full Centralization

The same two measures, service volume and service quality, were applied across the province to identify designated hospitals.

Scenario D7: Across the province, hospitals are ranked by cancer service volume, and the top one-third are designated as receiving hospitals. All cancer-service inpatient admissions province-wide are reassigned to this designated set.

Scenario D8: Across the province, hospitals are ranked by cancer service quality, and the top one-third are designated as receiving hospitals. All cancer-service inpatient admissions province-wide are reassigned to this designated set.

Data Sources and Sample

To simulate the impacts of different scenarios, we used individual-level patient data from the Guangdong Hospital Discharge Database, which includes all hospitalization records from medical institutions across Guangdong province from January 2017 to December 2023. Each record contains demographic information (ie, age, sex, residence location, and health insurance scheme), hospitalization characteristics and outcomes (ie, institution identifiers, expenditures, readmission, and in-hospital mortality), procedures coded using the International Classification of Diseases, 9th Revision, Clinical Modification, Volume 3, and diagnoses coded using the International Classification of Diseases, 10th Revision.

The study population consisted of inpatients aged 18 years or older who lived in one of the 57 counties of Guangdong province and who had a primary discharge diagnosis of COPD, pneumonia, or lung cancer. We also required complete hospitalization records, medical expenditures >0, and a length of stay of at least one day. To avoid survival bias, for patients with multiple admissions for the same condition within a given year, we randomly selected one admission per year following previous research.[26,28]

Impacts of County Health Services Reorganization

To evaluate the impact of reorganizing inpatient services, we assessed all 11 scenarios using three sets of outcome indicators: patient outcomes, healthcare expenditure and system workload. Patient outcomes included 31-day readmission rates, in-hospital mortality, and length of stay. Healthcare expenditure consisted of total hospitalization expenses and out-of-pocket (OOP) inpatient expenses. System workload was calculated as the ratio of outflow patients to the system's potential spare capacity. This indicator characterizes the relationship between the distribution of patients outside the designated healthcare facilities under different reorganization scenarios and the region-wide potential spare capacity, providing supplementary information on potential regional resource pressures. Potential spare capacity was defined as the difference between the system's maximum inpatient volume and the current number of patients within the system. The system's maximum inpatient volume was determined by multiplying its maximum monthly capacity by 12. The formula is as follows:

System workload = the number of outflow patients/(maximum monthly capacity of a system × 12 − number of patients remaining in this system)

Statistical Analysis

To estimate the expected impact of each of the eleven simulated allocation scenarios, we adopted an approach based on inverse-probability-weighted regression adjustment (IPWRA). This causal inference method combines inverse probability weighting and outcome regression.[29,30] For each scenario, patients from each county were classified as adherers or non-adherers on the basis of whether their observed admission location during 2017–2023 matched the scenario rule. Adherers composed the control group, whereas non-adherers composed the treated group. For example, in a county-only scenario that requires all admissions to occur within the patient's home county, adherers had in-county admissions, whereas non-adherers had out-of-county admissions. We then applied the IPWRA to estimate the

counterfactual mean outcome for the treated group. This estimate represents what patients' outcomes would have been if they had been admitted in accordance with the scenario rule.

The analysis proceeded in three steps. First, we estimated inverse-probability weights by modeling the probability of each patient being a non-adherer (ie, being admitted outside the specified site) conditional on the observed covariates. These weights were then used to balance the covariates between non-adherers (the treated group) and adherers (the control group). Second, we fitted outcome regression models using only the control group and applied the estimated weights. These models related patient characteristics to each outcome of interest, including in-hospital mortality, 31-day readmission, length of stay, total hospitalization cost and OOP cost. Third, we used fitted models to predict each patient's expected outcome if the scenario was implemented. Although predictions were generated for all patients, subsequent analyses focused on the treated group because, in this scenario, only non-adherers' admission location would be reassigned; adherers already complied with the rule in the observed data. For each outcome, we report two figures for the treated group: the observed mean under the current system and the predicted counterfactual mean under the scenario. These estimates were presented side by side to characterize the expected implications of the scenario for patient outcomes, healthcare expenditure and system workload.

For the county-level scenarios (A, B, and C), we conducted the analysis for each county separately and then aggregated the results, which were weighted by the number of individuals in the treated group in each county. For city-level scenarios (D1–D6), we performed the analysis at the city level and then aggregated the results across cities using the same weighting approach. For scenarios D7 and D8, we estimated the aggregate average effects for the entire study population directly.

To evaluate the robustness of the results, we applied alternative causal estimators,[31] including propensity score matching, inverse probability of treatment weighting and outcome regression. We then compared the resulting estimates with those obtained using the main approach. Given that the IPWRA approach involves both weighting and outcome prediction, we performed three additional checks specific to this approach: (1) assessing the balance of covariates after weighting; (2) replacing the parametric outcome model with a super learner (SL) ensemble to enable more flexible outcome prediction; and (3) evaluating the fit of the outcome model by comparing its predicted outcomes for the control group with their observed means.

The 95% confidence interval was calculated using the bootstrap method. All the statistical analyzes were conducted using R version 4.4.3 and StataSE 17. More details about the models are provided in Supplementary file 1.

Results

Study Population

From January 2017 to the end of 2023, we identified 731 148 admissions for COPD, 883 273 for pneumonia, and 147 158 for lung cancer among the residents of 57 counties in Guangdong province (Table 2). The mean age of patients admitted for COPD was 74.2 years. Among the patients, 72.3% were male and 83.2% were covered by urban and rural residents' medical insurance. The mean age of the patients admitted for pneumonia was 63.7 years. The majority (91.2%) were married, and 80.6% had urban and rural residents' medical insurance. The mean age of patients admitted for lung cancer was 65.4 years. More than half (59.2%) underwent surgery. With respect to hospitalization flows, most COPD and pneumonia admissions occurred within the patient's home county (89.2% and 86.3%, respectively), with smaller proportions occurring in other districts within the same city (6.5% and 7.7%, respectively) or in Guangzhou (0.9% and 2.2%, respectively). In contrast, lung cancer admissions showed greater outward flow: 42.6% occurred within the home county, 22.6% went to other districts within the same city, and 26.4% went to Guangzhou.

Effects of Decentralization Scenarios

Counterfactual outcomes under Scenarios A–C were compared with the corresponding observed outcomes (Table 3).

For COPD, the proportions of admissions requiring reassignment to the scenario-designated facilities were 10.8% in Scenario A (79 220/731 148), 47.1% in Scenario B (344 656/731 148), and 38.6% in Scenario C (282 451/731 148). Among patients requiring reassignment under Scenario A, the simulated readmission rate was 6.91% (vs. 4.84% observed), mortality was 0.68% (vs. 0.54% observed), length of stay was 8.21 days (vs. 8.14 days observed), total expenditures were CNY 9491 (vs. CNY 11 763 observed), and OOP expenditures were CNY 2797 (vs. CNY 4524 observed). Under Scenario B, the corresponding simulated outcomes were a readmission rate of 5.84% (vs. 7.09% observed), mortality of 0.79% (vs. 0.26% observed), length of stay of 7.34 days (vs. 6.46 days observed), total expenditures of CNY 6970 (vs. CNY 5381 observed), and OOP expenditures of CNY 2137 (vs. CNY 1619 observed). Under Scenario C, the simulated readmission rate was 6.58% (vs. 6.63% observed), mortality was 0.75% (vs. 0.32% observed), length of stay was 7.30 days (vs. 6.88 days observed), total expenditures were CNY 7055 (vs. CNY 6501 observed), and OOP expenditures were CNY 2281 (vs. CNY 2031 observed). At the county level, simulated mortality rates were higher than the observed rates in most counties under Scenarios B and C, whereas the pattern was more mixed under Scenario A (Figure 2 and Table S2). Average hospitalization costs decreased in most counties under Scenarios A and C but increased in most counties under Scenario B (Table S3). Only three counties showed estimated workload levels above 100% relative to regional potential spare capacity (Table S4).

For pneumonia, the proportions of admissions requiring reassignment to the scenario-designated facilities were 13.7% in Scenario A (121 257/883 273), 50.0% in Scenario B (441 747/883 273), and 38.4% in Scenario C (339 542/883 273). Among patients requiring reassignment under Scenario A, the simulated 31-day readmission rate was 6.87% (vs. 7.46% observed), mortality was 4.94% (vs. 2.27% observed),

Table 2. Characteristics of Patients Before Service Reconfiguration in 57 Counties of Guangdong Province

Variable	COPD (N = 731 148)	Pneumonia (N = 883 273)	Lung cancer (N = 147 158)
Age, mean (SD)	74.2 (10.1)	63.7 (17.0)	65.4 (11.6)
Sex, n (%)			
Male	528 563 (72.3%)	455 848 (51.6%)	99 507 (67.6%)
Female	202 585 (27.7%)	427 425 (48.4%)	47 651 (32.4%)
Marital status, n (%)			
Not married	60 677 (8.3%)	78 000 (8.8%)	7118 (4.8%)
Married	670 471 (91.7%)	805 273 (91.2%)	140 040 (95.2%)
Health insurance scheme, n (%)			
Urban employee resident insurance	84 343 (11.5%)	114 632 (13.0%)	28 483 (19.4%)
Urban and rural residents' medical insurance	608 428 (83.2%)	711 614 (80.6%)	88 056 (59.8%)
Self-pay	38 377 (5.2%)	57 027 (6.5%)	30 619 (20.8%)
Occupation, n (%)			
Employed	123 006 (16.8%)	196 699 (22.3%)	53 334 (36.2%)
Farmer	456 388 (62.4%)	521 796 (59.1%)	59 589 (40.5%)
Retired	61 348 (8.4%)	61 862 (7.0%)	13 168 (8.9%)
Unemployed	90 406 (12.4%)	102 915 (11.7%)	21 067 (14.3%)
CCI, mean (SD)	0.7 (0.9)	0.7 (1.0)	0.9 (1.0)
Surgical procedure, n (%)			
No	657 111 (89.9%)	764 542 (86.6%)	60 046 (40.8%)
Yes	74 037 (10.1%)	118 731 (13.4%)	87 112 (59.2%)
Year of hospitalization, n (%)			
2017	76 955 (10.5%)	58 503 (6.6%)	17 175 (11.7%)
2018	98 636 (13.5%)	81 053 (9.2%)	19 749 (13.4%)
2019	118 674 (16.2%)	126 064 (14.3%)	20 941 (14.2%)
2020	97 139 (13.3%)	104 431 (11.8%)	20 774 (14.1%)
2021	98 584 (13.5%)	111 961 (12.7%)	21 974 (14.9%)
2022	111 366 (15.2%)	145 553 (16.5%)	22 327 (15.2%)
2023	129 794 (17.8%)	255 708 (29.0%)	24 218 (16.5%)
Admission to primary care facilities, n (%)			
No	462 640 (63.3%)	558 099 (63.2%)	138 936 (94.4%)
Yes	268 508 (36.7%)	325 174 (36.8%)	8222 (5.6%)
Patient flow type[a], n (%)			
Within county	651 928 (89.2%)	762 016 (86.3%)	62 664 (42.6%)
Other counties in same city	12 942 (1.8%)	14 337 (1.6%)	2958 (2.0%)
Other districts in same city	47 350 (6.5%)	67 901 (7.7%)	33 195 (22.6%)
Other counties in other cities	2331 (0.3%)	2872 (0.3%)	818 (0.6%)
Other districts in other cities	9656 (1.3%)	16 629 (1.9%)	8655 (5.9%)
Guangzhou city[b]	6941 (0.9%)	19 518 (2.2%)	38 868 (26.4%)

Abbreviations: COPD, chronic obstructive pulmonary disease; SD, standard deviation; CCI, Charlson Comorbidity Index.
Note: [a]The patient flow type refers to the actual distribution of patients, which is defined by the Chinese administrative levels. "District" refers to urban districts, while "county" refers to county-level units. [b]Guangzhou is the capital city of Guangdong province.

length of stay was 10.00 days (vs. 9.80 days observed), total expenditures were CNY 13 857 (vs. CNY 22 066 observed), and OOP expenditures were CNY 4477 (vs. CNY 9027 observed). Under Scenario B, the corresponding simulated outcomes were a readmission rate of 5.18% (vs. 5.47% observed), mortality of 1.66% (vs. 0.76% observed), length of stay of 7.49 days (vs. 6.51 days observed), total expenditures of CNY 7725 (vs. CNY 8127 observed), and OOP expenditures of CNY 2475 (vs. CNY 2981 observed). Under Scenario C, the simulated readmission rate was 5.71% (vs. 5.84% observed), mortality was 1.83% (vs. 1.00% observed), length of stay was 7.43 days (vs. 8.86 days observed), total expenditures were CNY 8175 (vs. CNY 10 405 observed), and OOP expenditures were CNY 2861 (vs. CNY 3916 observed). At the county level, simulated mortality rates were higher than the observed rates in most counties under all three scenarios (Figure 2

Table 3. Estimated Impacts for Three Decentralization Scenarios

Outcome	Scenario A		Scenario B		Scenario C	
	Counterfactual[a]	Observed[b]	Counterfactual[a]	Observed[b]	Counterfactual[a]	Observed[b]
COPD						
Number of patients moving to alternative facilities[c]	79 220		344 656		282 451	
Expected 31-day readmission rates (95% CI)	6.91% (6.29%, 7.58%)	4.84% (4.69%, 4.99%)	5.84% (5.46%, 6.33%)	7.09% (7.00%, 7.18%)	6.58% (6.05%, 7.20%)	6.63% (6.54%, 6.73%)
Expected mortality rates (95% CI)	0.68% (0.51%, 0.92%)	0.54% (0.49%, 0.59%)	0.79% (0.65%, 0.94%)	0.26% (0.25%, 0.28%)	0.75% (0.61%, 0.92%)	0.32% (0.30%, 0.34%)
Expected length of stay (95% CI)	8.21 (7.79, 8.73)	8.14 (8.09, 8.19)	7.34 (7.10, 7.62)	6.46 (6.42, 6.51)	7.30 (7.03, 7.57)	6.88 (6.84, 6.93)
Expected total healthcare expenditures[d] (95% CI)	9490.78 (8569.64, 10 551.00)	11763.45 (11626.84, 11900.06)	6970.08 (6483.34, 7617.46)	5380.89 (5347.25, 5414.53)	7054.59 (6488.84, 7700.34)	6500.80 (6460.57, 6541.04)
Expected OOP expenditures[d] (95% CI)	2796.74 (2438.95, 3252.34)	4523.53 (4456.16, 4590.90)	2137.05 (1790.74, 2519.05)	1618.81 (1602.84, 1634.78)	2280.60 (2015.06, 2618.27)	2031.10 (2011.60, 2050.59)
Pneumonia						
Number of patients moving to alternative facilities[c]	121 257		441,747		339 542	
Expected 31-day readmission rates (95% CI)	6.87% (5.77%, 7.92%)	7.46% (7.31%, 7.61%)	5.18% (4.54%, 5.86%)	5.47% (5.40%, 5.53%)	5.71% (4.80%, 6.50%)	5.84% (5.76%, 5.91%)
Expected mortality rates (95% CI)	4.94% (3.97%, 6.00%)	2.27% (2.19%, 2.35%)	1.66% (1.32%, 2.05%)	0.76% (0.74%, 0.79%)	1.83% (1.41%, 2.25%)	1.00% (0.97%, 1.04%)
Expected length of stay (95% CI)	10.00 (9.26, 10.93)	9.80 (9.72, 9.88)	7.49 (7.17, 7.96)	6.51 (6.44, 6.58)	7.43 (7.06, 7.79)	8.86 (5.95, 11.78)
Expected total healthcare expenditures[d] (95% CI)	13 856.64 (12 630.67, 15 240.92)	22066.32 (21793.04, 22339.61)	7724.56 (7096.57, 8690.06)	8127.12 (8048.20, 8206.04)	8175.49 (7359.45, 8882.81)	10 405.49 (10 297.51, 10 513.47)
Expected OOP expenditures[d] (95% CI)	4477.02 (3804.09, 5314.79)	9027.00 (8869.44, 9184.57)	2474.90 (2063.91, 2984.27)	2981.18 (2937.71, 3024.65)	2860.90 (2513.15, 3316.00)	3915.57 (3858.40, 3972.74)
Lung Cancer						
Number of patients moving to alternative facilities[c]	27 159		35 133		38 082	
Expected 31-day readmission rates (95% CI)	16.58% (14.68%, 18.58%)	7.95% (7.63%, 8.29%)	15.30% (13.59%, 16.98%)	10.47% (10.16%, 10.79%)	15.61% (14.24%, 17.02%)	10.25% (9.95%, 10.56%)
Expected mortality rates (95% CI)	17.85% (13.90%, 22.02%)	3.82% (3.61%, 4.05%)	15.92% (12.76%, 19.49%)	4.22% (4.01%, 4.44%)	13.69% (10.62%, 16.97%)	4.31% (4.11%, 4.51%)
Expected length of stay (95% CI)	10.63 (9.89, 11.41)	9.07 (8.96, 9.18)	10.20 (9.58, 10.83)	9.03 (8.92, 9.14)	10.05 (9.36, 10.76)	8.99 (8.88, 9.09)
Expected total healthcare expenditures[d] (95% CI)	10 922.15 (10 004.22, 12 002.00)	17 409.11 (17 195.02, 17 623.21)	10 331.66 (9531.98, 11 299.78)	14 514.01 (14 339.51, 14 688.51)	9627.17 (8929.25, 10 417.52)	14 274.12 (14 111.84, 14 436.39)
Expected OOP expenditures[d] (95% CI)	3644.55 (2980.35, 4499.67)	8470.16 (8332.63, 8607.69)	3040.66 (2591.18, 3580.10)	6790.16 (6682.20, 6898.12)	3111.74 (2690.92, 3630.45)	6536.74 (6430.15, 6643.32)

Abbreviations: OOP, out-of-pocket; CI, confidence interval.

Note: [a] For patients who actually used other institutions, the counterfactual estimates capture the outcomes they would have experienced if admitted to the scenario-designated location. [b] Observed outcomes are the real-world outcomes for patients whose actual admission locations did not conform to the locations designated by the three scenarios. [c] The number of patients requiring reassignment refers to the number of patients whose actual admission locations differed from those specified in the three scenarios. Reallocation effects were evaluated by comparing these patients' observed outcomes at their actual admission locations with the counterfactual outcomes predicted after reassignment to the scenario-designated facilities. [d] All costs are reported in Chinese yuan (CNY).

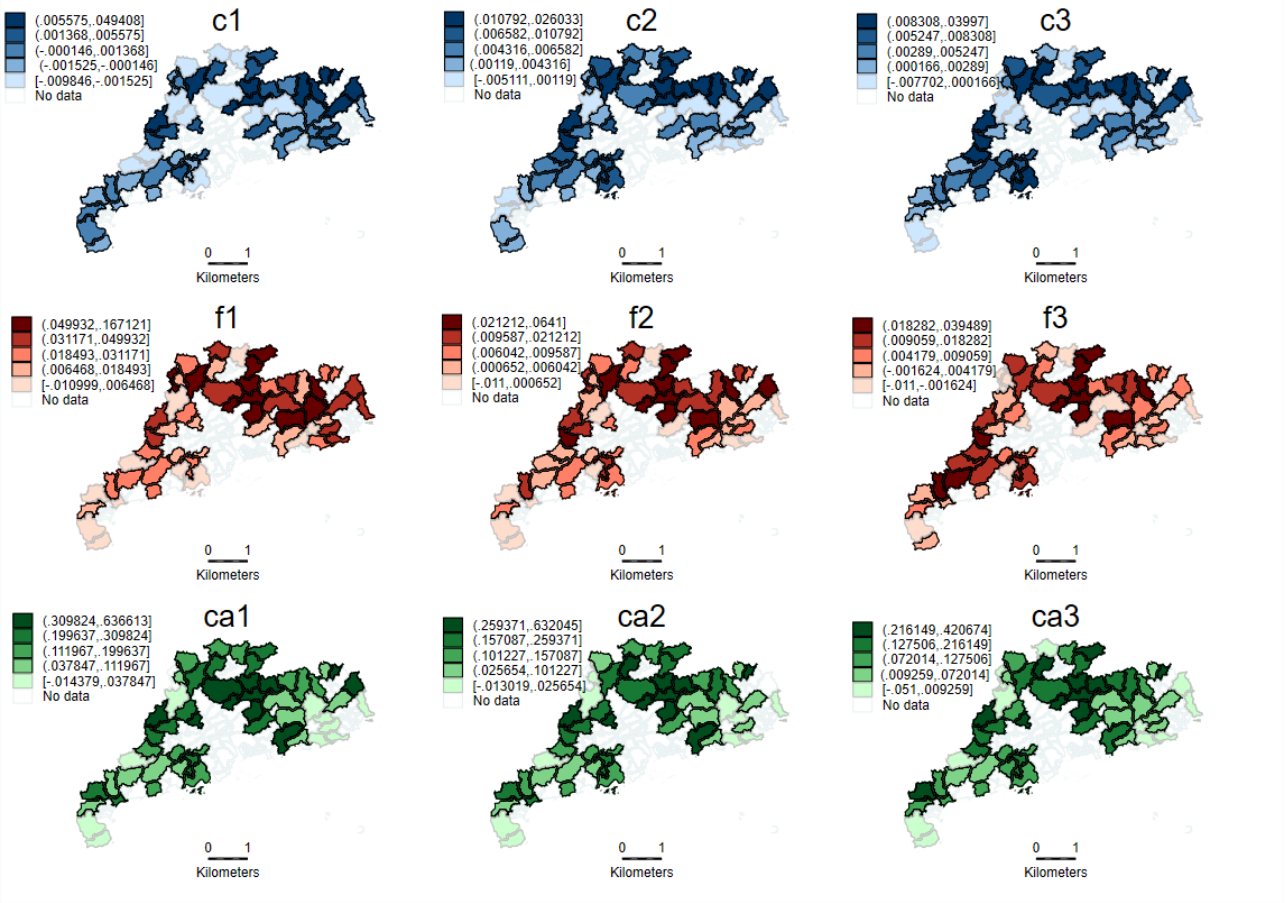


Figure 2. County-Level Impacts of Three Decentralization Scenarios on In-Hospital Mortality, Guangdong. Note: c1-c3, f1-f3, and ca1-ca3 show county-level in-hospital mortality for COPD, pneumonia, and lung cancer, respectively, under the three decentralization scenarios (A, B, C). The values represent simulated mortality minus observed mortality (percentage points), indicating each scenario's impact at the county level. Darker colors indicate counties where simulated mortality exceeds observed mortality by a greater margin.

and Table S2), while average hospitalization costs decreased in most counties under all three scenarios (Table S3). Only four counties showed estimated workload levels above 100% relative to regional potential spare capacity (Table S5).

For lung cancer inpatient care excluding complex surgical cases, 27 159–38 082 admissions required reassignment across Scenarios A–C. Across all three scenarios, simulated 31-day readmission rates were higher than the observed rates (15.30%–16.58% vs. 7.95%–10.47%), as were mortality rates (13.69%–17.85% vs. 3.82%–4.31%) and length of stay (10.05–10.63 vs. 8.99–9.07 days). In contrast, simulated total expenditures were lower (CNY 9627–10 922 vs. CNY 14 274–17 409 observed), as were OOP expenditures (CNY 3041–3645 vs. CNY 6537–8470 observed). At the county level, simulated mortality rates were higher than the observed rates in most counties under all three scenarios, while average hospitalization costs decreased in most counties under all three scenarios. County-level regional service capacity was substantially constrained, with the estimated workload exceeding 100% of the residual service capacity in most counties (Table S6, Supplementary file 2).

Effects of Centralization Scenarios

For complex lung cancer surgical inpatient services, 6030–41 620 admissions required reassignment across Scenarios D1–D8 (Table 4). Under D1–D6, simulated mortality rates were higher and lengths of stay were longer than observed, while total and OOP expenditures were consistently lower. Simulated 31-day readmission rates were also higher in D1, D2, and D4–D6, but lower in D3. Across these six scenarios, total expenditures decreased by approximately CNY 7432–17 227 per admission and OOP expenditures by CNY 7338–11 431. In contrast, substantially fewer admissions required reassignment under D7 and D8 (6030–10,231), and both scenarios showed lower readmission rates (4.71%–5.21% vs. 8.31%–10.41% observed) and mortality rates (1.56%–1.83% vs. 6.17%–7.05% observed), with similar lengths of stay (13.05–13.21 vs. 13.31–13.46 days). However, total expenditures were higher (CNY 34 327–36 642 vs. CNY 20 324–25 926 observed), as were OOP expenditures (CNY 13 789–16 520 vs. CNY 6895–9641 observed).

At the city level, analyses were conducted for D1–D6. Simulated in-hospital mortality was higher than observed in most cities under all six scenarios, ranging from 11 to 14 of the 15 cities depending on the scenario (Table S7). Reductions in readmission were concentrated mainly in D1–D4, with simulated readmission rates lower than observed in 11–12 cities, compared with only six cities under D5 and D6 (Table S8). Simulated total hospitalization costs were lower than observed in all 15 cities under each of D1–D6

Table 4. Estimated Impacts of Eight Centralization Scenarios for Complex Lung Cancer Inpatient Care

Scenarios	Number of Patients Moving to Alternative Facilities[a]	Expected 31-Day Readmission Rates (95% CI)	Expected Mortality Rates (95% CI)	Expected Length of Stay (95% CI)	Expected Total Healthcare Expenditures[b] (95% CI)	Expected OOP expenditures[b] (95% CI)
D1						
Counterfactual[c]	39 264	6.86% (4.47%, 10.49%)	3.09% (1.79%, 5.15%)	13.99 (12.61, 15.46)	34 140.12 (29 558.55, 38 187.14)	15 738.04 (13 125.79, 18 013.13)
Observed[d]		5.57% (5.34%, 5.80%)	1.23% (1.12%, 1.34%)	11.78 (11.68, 11.87)	49 166.23 (48 782.98, 49 549.47)	25 943.47 (25 683.27, 26 203.67)
D2						
Counterfactual[c]	41 620	6.24% (4.31%, 10.50%)	3.20% (1.83%, 5.55%)	13.89 (12.72, 14.93)	32 305.55 (28 209.86, 35 598.41)	14 543.02 (12 549.57, 16 157.85)
Observed[d]		6.10% (5.87%, 6.33%)	1.46% (1.35%, 1.57%)	11.82 (11.73, 11.91)	48 324.34 (47 953.12, 48 695.56)	25 165.55 (24 923.65, 25 407.46)
D3						
Counterfactual[c]	37 435	4.44% (3.50%, 5.59%)	3.19% (1.88%, 5.26%)	13.72 (12.53, 14.77)	33 218.03 (29 155.62, 36 526.24)	15 401.84 (13 042.14, 17 563.27)
Observed[d]		5.44% (5.22%, 5.67%)	1.05% (0.95%, 1.15%)	11.65 (11.55, 11.74)	50 444.87 (50 058.10, 50 831.63)	26 833.24 (26 574.26, 27 092.21)
D4						
Counterfactual[c]	40 369	6.27% (4.30%, 10.58%)	3.29% (1.90%, 5.65%)	13.81 (12.70, 14.84)	31 984.24 (27 880.95, 35 538.30)	14 480.58 (12 435.92, 16 132.83)
Observed[d]		6.08% (5.85%, 6.31%)	1.42% (1.31%, 1.54%)	11.78 (11.69, 11.87)	49 107.15 (48 741.10, 49 473.19)	25 735.20 (25 486.36, 25 984.05)
D5						
Counterfactual[c]	34 710	6.17% (4.97%, 7.66%)	2.05% (1.35%, 2.94%)	12.71 (12.24, 13.27)	41 410.71 (37 599.47, 44 384.63)	18 390.40 (15 759.14, 20 515.75)
Observed[d]		5.54% (5.30%, 5.78%)	1.34% (1.23%, 1.46%)	11.93 (11.83, 12.03)	48 842.36 (48 437.82, 49 246.91)	25 728.12 (25 463.83, 25 992.40)
D6						
Counterfactual[c]	35 410	6.22% (5.10%, 7.60%)	2.04% (1.37%, 2.91%)	12.78 (12.24, 13.40)	40819.68 (37 235.22, 43 458.21)	17 837.68 (15 450.54, 19 962.54)
Observed[d]		5.75% (5.52%, 5.99%)	1.62% (1.50%, 1.76%)	11.91 (11.80, 12.01)	48 487.98 (48102.21, 48873.75)	25 290.01 (25 035.59, 25 544.42)
D7						
Counterfactual[c]	6030	5.21% (4.31%, 5.92%)	1.83% (1.37%, 3.00%)	13.05 (12.74, 13.61)	34 326.81 (29 168.70, 36 802.11)	137 88.99 (11 521.96, 15 472.37)
Observed[d]		8.31% (7.65%, 9.01%)	7.05% (6.42%, 7.73%)	13.46 (13.07, 13.85)	20 324.05 (19 721.67, 20 926.44)	6895.06 (6600.80, 7189.32)
D8						
Counterfactual[c]	10 231	4.71% (4.17%, 5.28%)	1.56% (1.12%, 2.74%)	13.21 (12.92, 13.62)	36 642.05 (30 818.11, 37 899.39)	16 519.71 (13 539.90, 17 318.80)
Observed[d]		10.41% (9.83%, 11.02%)	6.17% (5.73%, 6.64%)	13.31 (13.08, 13.55)	25 925.80 (25 411.26, 26 440.34)	9640.52 (9402.31, 9878.73)

Abbreviations: OOP, out-of-pocket; CI, confidence interval.

Note: [a] The number of patients requiring reassignment refers to the number of patients whose actual admission locations differed from those specified in these scenarios. [b] All costs are reported in Chinese yuan (CNY). [c] For patients who actually used other institutions, the counterfactual estimates capture the outcomes they would have experienced if admitted to the scenario-designated location. Reallocation effects were evaluated by comparing these patients' observed outcomes at their actual admission locations with the counterfactual outcomes predicted after reassignment to the scenario-designated facilities. [d] Observed outcomes are the real-world outcomes for patients whose actual admission locations did not conform to the locations designated by these scenarios.

(Table S9). Estimated workload relative to regional potential spare capacity differed across scenarios, with higher levels under D1–D4, lower levels under D5–D6, and relatively low levels under D7 and D8 (Table S10, Supplementary file 3).

Sensitivity Analysis

The simulation results for the four methods are shown in Tables S11–S12 (Supplementary file 4) and are essentially consistent. The results of the sensitivity analyses, which include SMD balance checks, SL models, and control group mean comparisons, are shown in Tables S13–S17 (Supplementary file 5).

Discussion

In this study, a conceptual framework for reorganizing county-level inpatient services was developed and administrative data from Guangdong province were used to simulate 11 allocation scenarios. Our results indicate that centralization strategies may improve patient outcomes but are generally associated with higher inpatient costs. Decentralization scenarios, in contrast, vary across contexts. Their potential benefits and challenges depend on the specific context of the healthcare system and the types of diseases being treated. These findings provide evidence for assessing the suitability of different allocation schemes, thereby informing regional health service planning.

Across the three decentralization scenarios, hospitalization costs decreased in most settings, whereas in-hospital mortality increased. These results align with prior research that reported that the quality of healthcare services was perceived to be worse after decentralization than before implementation.[32] This may be because decentralization shifts service provision to a wider set of local providers. These providers may have uneven managerial, financial and human-resource capacity.[33] Decentralization can also fragment service delivery and further amplify shortages of staff and essential medicines in resource-limited areas.[34,35] We also found that the increase in mortality was disease specific, with a sharp increase for lung cancer but a much smaller increase for COPD and pneumonia. This heterogeneity is plausible because inpatient cancer care typically requires a more specialized workforce and a broader range of supporting resources, such as diagnostic services, oncology treatment and monitoring, and complication management.[36] If these inputs are distributed unevenly across facilities, reallocating inpatient care within counties may compromise safety for higher-risk patients. Therefore, any policy shift toward decentralized inpatient care should be accompanied by targeted investments in workforce training, resource standardization and strengthening of the referral system. These measures would help ensure that cost efficiency gains do not compromise patient safety.

In recent years, many high-income countries have pursued the centralization of complex surgical services to improve outcomes.[1,5] Building on this experience, we investigated whether the same principles could be applied to the restructuring of inpatient services at the county level in China. Our simulations revealed that centralization at the provincial level (D7 and D8) improved patient outcomes. In contrast, the six city-level centralization schemes achieved minimal improvement, primarily because many county residents were already receiving care in the same hospitals that had been designated in D7 and D8. This left limited scope for further gains from a lower-tier design. Moreover, centralization was linked to higher inpatient costs, highlighting the importance of aligning payment policies to avoid passing on additional costs to patients. Despite these trade-offs, our findings suggest that concentrating complex lung cancer surgeries in a small number of specialist hospitals is an effective way of improving outcomes. Pilot programs or phased implementation may help test feasibility before wider adoption. Beyond the study setting, other regions can adapt the planning toolkit by expanding the outcome metrics to reflect local priorities, such as affordability and geographic accessibility. Policy-makers can then iteratively test configurations to identify county-specific service boundaries and minimum capacity thresholds.

Substantial resource investment is required for major systemic reforms, so pre-implementation simulation is essential to anticipate the consequences. Our estimates were derived from such simulations rather than from observed rollouts, making it important to clarify the approach to prediction. We used a counterfactual prediction method based on IPWRA and used the outcomes of those who adhered to the rules as a reference. We then applied inverse probability weights to balance the observed covariates between adherents and non-adherents, which allowed us to predict the outcomes for non-adherents based on the basis of the experiences of adherents. This counterfactual prediction approach is not unique to the present study. For example, a previous study estimated ordered logit regressions for each state using data from 2012 with the dependent variable representing the level of 9928X coding for emergency department visits.[37] These coefficients were then applied to the 2019 data to predict the level of 9928X coding that would have been assigned if patients in 2019 had been coded according to 2012 practices. Upcoding was identified by calculating the difference between the actual 9928X code assigned to a patient and the predicted code based on the 2012 regression coefficients. Another study of cancer service centralization used a conditional logit regression model to predict the probability that each patient would be treated at each remaining hospital (ie, those that would remain available after the proposed centralization) on the basis of travel time, hospital characteristics, and patient characteristics.[27] These probabilities were subsequently used to calculate the expected weighted average travel time after centralization. Discrete-event simulation and system dynamics are also widely used for the prospective appraisal of policies.[38,39] Despite their differing modeling frameworks, these methods rely on real-world data to estimate or calibrate key parameters and to project outcomes under specified rules. The credibility of these approaches ultimately depends on the plausibility of the assumptions made and the quality of the data used. Administrative data and statistical models may not fully capture behavioral responses following the implementation of policies. Therefore, future research could combine quantitative simulation with qualitative inquiry to

address these gaps.

The main contribution of this study is the development of a toolkit for reorganizing county-level inpatient services. This toolkit covers the analytical process from the conceptual framework and scenario design to counterfactual simulations using administrative data. The case of Guangdong province was used to demonstrate how the toolkit could be applied to translate allocation rules into estimates of clinical outcomes and costs. Instead of suggesting specific numerical goals, the toolkit provides a method that can be customized with local data. It helps regions identify which services should be prioritized for reorganization, using data on utilization, outcomes, and expenditure. It also estimates how decentralization or centralization may affect safety, costs, and efficiency, thereby helping define service boundaries and minimum capacity requirements. Because the assessment is ex ante, the toolkit can be used iteratively to update decisions in line with changes to policy objectives.

Our study has several limitations. First, the analysis focused on hospitalizations for respiratory diseases, which limited its generalizability to other conditions. Second, the administrative data lacked laboratory and imaging information, which may have affected assessments of severity. To mitigate this issue, we included available proxies related to severity, such as the comorbidity index, surgical status, and case classification. Third, misclassification or miscoding is a concern in administrative datasets, but routine audits by the Guangdong Provincial Health Department helped to support data quality. Fourth, owing to data limitations, the study examined in-hospital mortality and readmission rates rather than measuring healthcare service capability directly. Fifth, our conceptual framework took a general approach that was informed by international experience rather than providing a prescriptive list of services to be centralized or decentralized. Sixth, our empirical simulations used Guangdong province as a case in point, and the estimates were specific to this context rather than providing generalizable numerical benchmarks for other provinces. The value lies in the transferable scenario framework itself. Seventh, we defined centralization and decentralization on the basis of service location without addressing governance, financing, or resource allocation mechanisms. Because this was a pre-implementation assessment, we prioritized evaluating potential effects over implementation mechanisms. An additional limitation concerns the measurement of system workload. This indicator estimates the proportion of regional potential spare capacity occupied by patients treated outside designated healthcare facilities, providing an indication of the potential pressure on existing regional service capacity. The maximum capacity was based on all healthcare facilities within each region. Future studies could use facility-specific maximum capacity data to better assess the capacity implications of service reorganization. Finally, because individual geographical location data were unavailable, our centralization scenarios did not incorporate proximity-based hospital assignment (ie, assigning each resident to the nearest facility). This approach was consistent with our focus on clinical outcomes rather than geographical accessibility.

Conclusions

In this study, a toolkit was developed to reorganize county-level inpatient services, and this reorganization was used to simulate eleven scenarios in Guangdong. The results showed that centralization improved clinical outcomes but increased costs, whereas decentralization reduced costs but potentially compromised safety for complex conditions. This toolkit can enable other regions to model potential outcomes in advance and can help policy-makers calibrate the degree of centralization or decentralization on the basis of local service capacity and resource availability.

Disclosure of artificial intelligence (AI) use

Section(s) of manuscript affected: Abstract, Background, Methods, and Discussion.
Type of AI tool(s) used: ChatGPT and Claude.
Purpose of use: Language editing and grammar checking.

Ethical issues

This study was approved by the Ethics Committee of the School of Public Health, Sun Yat-Sen University (No: 2024-038, approved on March 4, 2024).

Conflicts of interest

Authors declare that they have no conflicts of interest.

Authors' contributions

Conceptualization: Yixiang Huang and Yi Zhu.
Data curation: Xiaoliang Huang and Wei Hu.
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Funding acquisition: Yixiang Huang and Xiaoliang Huang.
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Writing–review & editing: Yixiang Huang, Yi Zhu, and Shengliang Chen.

Funding statement

Research reported in this publication was supported by the National Natural Science Foundation of China under Award No.72474235 and Guangdong Province Science and Technology Plan Project under Award 2024B1212070015.

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Supplementary files

These supplementary documents provide detailed methodological and analytical information to support the main findings. It includes descriptions of statistical methods, covariate selection, predictive modeling, sensitivity analyses, and scenario-based impact analyses relating to inpatient services for COPD, pneumonia, and lung cancer.

Supplementary file 1 provides an introduction to four analytical methods and includes Table S1, which lists the covariates included in the models.

Supplementary file 2, with Tables S2–S6, presents county-level outcome and system-capacity analyses under the three decentralization scenarios.

Supplementary file 3, with Tables S7–S10, presents city-level outcome analyses under the first six centralization scenarios and system-workload analyses under all eight centralization scenarios.

Supplementary file 4, Tables S11–S12, shows the results of the four methods.

Supplementary file 5, with Tables S13–S17, reports sensitivity analyses, including Standardized Mean Difference balance checks, a SL model and control group mean comparisons.

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