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Research Article

Keywords: National Centralized Drug Procurement, anesthetics, utilization analysis, interrupted time series

Posted Date: February 27th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-8624448/v1

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Additional Declarations: No competing interests reported.

Beyond the Price Cut: Utilization Trends of Anesthetic Drugs Before and After Centralized Procurement

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Abstract

Background: China's National Centralized Drug Procurement (NCDP) aims to lower drug costs and improve drug access. Beyond the price cut, the inclusion of anesthetics has raised concerns about potential impacts on clinical efficacy and safety, yet empirical evaluations remain limited.

Objective: To assess changes in anesthetic drug utilization following NCDP implementation, focusing on average dosage per procedure and the usage patterns.

Methods: A retrospective study using 2019–2025 prescription data from a tertiary hospital in eastern China. Four procured anesthetics and two drug regimens were analyzed and semi-structured interviews were conducted with anesthesiologists. Propensity score matching adjusted for patient characteristics. Interrupted time series analysis assessed dosage changes.

Results: Most anesthetics showed short-term changes in dosage and usage post-implementation but stabilized within a year. Dosage remained within clinically appropriate ranges, and no significant shifts were observed in regimens. Qualitative findings suggested adaptation in clinical practice without compromise to care quality.

Conclusion: The NCDP's inclusion of anesthetic drugs led to temporary prescribing adjustments, followed by stable long-term use. From the perspective of dosage, no evidence indicated reduced efficacy of NCDP anesthetic drugs.

Trial registration: Not applicable.

Keywords

National Centralized Drug Procurement; anesthetics; utilization analysis; interrupted time series

1 Background

In recent years, the Chinese government has introduced the National Centralized Drug Procurement Policy (NCDP) to curb drug prices and reduce the financial burden of medication for the public. In January 2019, the General Office of the State Council issued the *Pilot Plan for the National Centralized Procurement and Use of Drugs*, which officially proposed the national drug procurement policy for the first time [1]. The NCDP is led by government bodies including the healthcare security department, the drug regulatory authority, and the health department. It operates by consolidating the procurement demands of public medical institutions across different regions, determining specific procurement volumes, and conducting centralized bidding processes [2]. Drugs participating in the bidding must pass the Generic Consistency Evaluation, and the bid-winning drugs are selected based on the quoted prices. Companies of the bid-winning drugs are then able to secure the majority of the market share within public hospitals [3,4]. The NCDP has two main advantages. First, through open competition and bulk purchasing, it effectively encourages pharmaceutical manufacturers to offer lower prices in exchange for relatively stable market share and sales volumes. Second, the policy mandates that public medical institutions give priority to purchasing and using drugs selected through the centralized procurement process. It also sets compulsory usage targets, which, in effect, function as a form of consideration for the preferential pricing obtained through centralized procurement. The targets usually are set between 50% to 70% of the total procurement volume and are incorporated into performance evaluations. Guided by the policy, public hospitals have significantly increased both the procurement and clinical use of drugs from the centralized procurement list, thereby improving access to essential medicines.

At present, with the increasing number of general anesthesia procedures and day surgeries, the demand for anesthetic drugs has also grown, leading to the gradual inclusion of anesthetics in the national centralized procurement program. As of April 2025, the government has organized ten rounds of centralized drug procurement, which

now cover eight types of drugs used in general anesthesia procedures (Table 1). However, following the implementation of this policy, public concern has arisen around the so-called “anesthetics that don’t anesthetize” [5]. Due to price reductions, some physicians and patients worry that the clinical efficacy and safety of anesthetics included in the procurement program may be compromised. This public sentiment reflects a high level of sensitivity regarding the quality and clinical performance of anesthetic drugs, highlighting the urgent need for systematic research on their use.

Table 1. Anesthetic drugs included in the centralized drug procurement.

Drug Name	Round of NCDP
Dexmedetomidine hydrochloride injection	1st
Propofol medium-/long-chain fat emulsion injection	4th
Ropivacaine Hydrochloride Injection	5th
Cisatracurium Besylate Injection	5th
Rocuronium Bromide Injection	7th
Lidocaine Hydrochloride Injection	7th
Levobupivacaine hydrochloride injection	8th
Propofol emulsion for injection	9th

The anesthetic drugs discussed in this study refer to those for general anesthesia procedures as well as for local anesthesia procedures. In general anesthesia procedures, an ideal anesthetic state consists of three key components: loss of consciousness, adequate analgesia, and satisfactory muscle relaxation. To achieve these three components, general anesthesia typically requires the combined use of sedative-hypnotic drugs, opioid analgesics, and muscle relaxants [6], each category involving multiple drug options. For small to medium-sized surgeries that use local anesthesia—such as tooth extraction or endoscopic examinations—local anesthetics are used to temporarily and reversibly block nerve conduction in a specific part of the body. Currently, precision anesthesia and multimodal drug combinations have become the mainstream trends in clinical anesthetic practice [7]. This reflects the need for anesthetic management to select and combine multiple drugs based on surgical type, patient

condition, and required anesthesia depth, in order to develop individualized anesthetic regimens.

In recent years, research on anesthetic drugs has mainly focused on pharmacoeconomic evaluations, in-hospital management, and usage analyses. Some studies concentrate on the use of individual anesthetic drugs and lack systematic evaluations of multimodal drug combinations.

For example, Timon Vassiliou et al. [8] conducted a cost analysis to study the economic value of anesthetic drugs such as ropivacaine. In addition, some studies are limited by short observation periods, making them less responsive to policy interventions. Zhang Binghong et al. [9] analyzed the use of anesthetic drugs in a Shanghai hospital from January to June 2023, figuring out that the overall use of anesthetic drugs in this hospital is rational, but certain issues still exist. More importantly, there remains a shortage of research specifically examining how national centralized drug procurement policies influence in-hospital use of anesthetic drugs. For instance, Yao Yan et al. [10] used data from several medical institutions in Shanghai to study the use of anesthetic drugs, but the study did not fully consider the impact of centralized procurement. Therefore, it is of great significance to conduct an in-depth analysis of changes in the use of anesthetic drugs and shifts in usage patterns under the background of centralized procurement. Such research can help improve pharmaceutical policies and optimize the management of anesthetic drugs.

Based on this, the present study uses real-world data and focuses on multimodal anesthetic regimens. Given that the dosage of anesthetic drugs must be adjusted according to individual patient conditions, and that no standardized Defined Daily Dose (DDD) exists for such drugs, the study adopts two indicators—average dosage per procedure and proportion of use —to investigate clinical usage trends and evolving patterns. It further provides a systematic analysis of how different anesthetic regimens have been used following the implementation of the national centralized drug procurement policy.

This study approaches the issue from the perspective of “dosage” for two key reasons. First, the lack of a unified DDD standard for anesthetic drugs makes it difficult to measure usage intensity using conventional methods. Second, this perspective helps test the core research hypothesis: if a centrally procured drug performs poorly in actual clinical use, it may affect prescription behavior. Therefore, by using average dosage per procedure—a metric closely aligned with real clinical operations—the study can more sensitively capture the potential impact of centralized procurement on the structure of anesthetic drug use. This provides empirical support for both policy evaluation and clinical decision-making.

2 Data and Methods

2.1Data Source

All data used in this study were obtained from a tertiary hospital located in an eastern province of China. This hospital has an average of approximately 111,500 discharged patients annually and performs around 33,000 surgical procedures each year, with complex surgeries—classified as Grade III and IV—accounting for about 65% of the total surgical volume. The study collected all patient visit and prescription data from the hospital between January 1st, 2019, and March 31st, 2025. The data include patient information, drug names, specifications, manufacturers, unit prices, and dosage.

2.2 Study Subjects and Indicators

This study focuses on the use of anesthetic drugs, specifically examining the immediate trends following the inclusion of those drugs. The sample hospital used 6 procured anesthetic drugs: dexmedetomidine hydrochloride injection, Ropivacaine Hydrochloride Injection, Cisatracurium Besylate Injection, Rocuronium Bromide Injection, Lidocaine Hydrochloride Injection, and propofol injectable emulsion. The following exclusion criteria were applied: (1) Anesthetic adjuvants that, when used alone, cannot achieve any of the desired effects—sedation, analgesia, muscle relaxation, or local anesthesia—were excluded. (2) Drugs that had been implemented in centralized

procurement for one year or less were also excluded (Figure 1).

After excluding, four anesthetic drugs were included in the final analysis: Ropivacaine Hydrochloride Injection, Cisatracurium Besylate Injection, Rocuronium Bromide Injection, and Lidocaine Hydrochloride Injection. According to relevant guidelines [6,11-13], the sample drugs were categorized into two main groups: drugs for general anesthesia and local anesthetics. Specifically, Cisatracurium Besylate Injection and Rocuronium Bromide Injection belong to muscle relaxant category under drugs for general anesthesia.

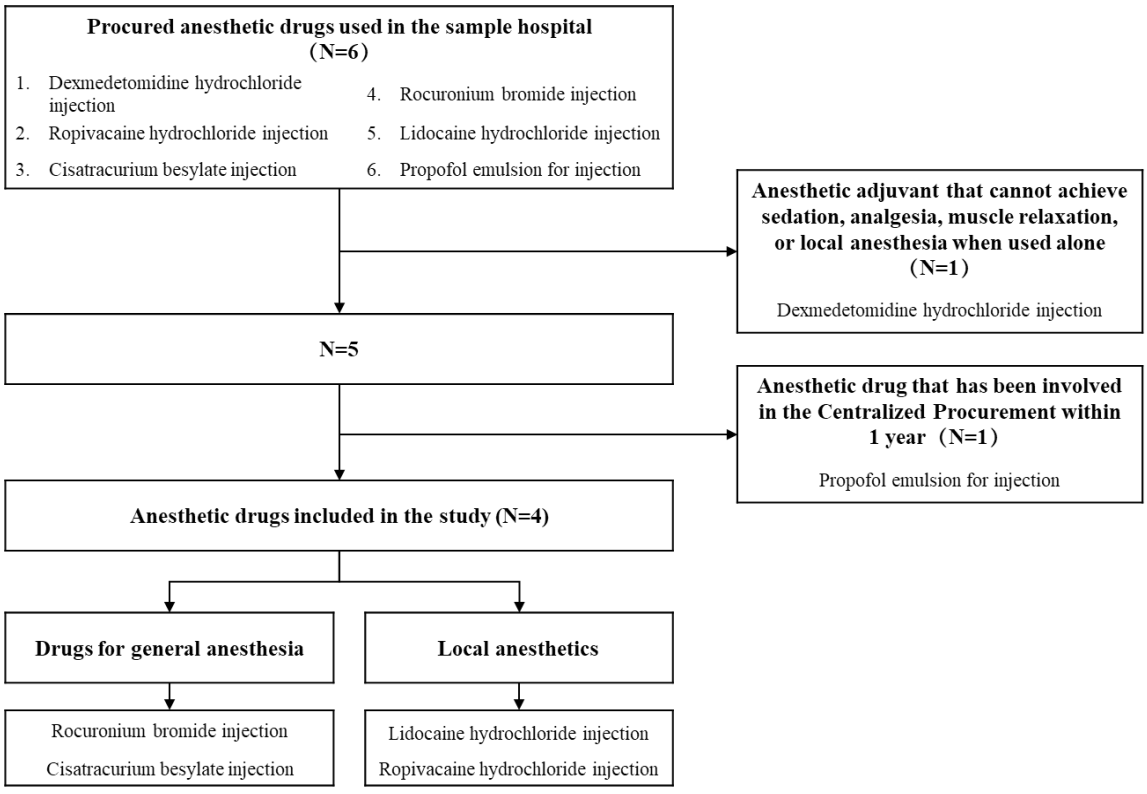


Figure 1. Flow diagram for drug selection of the study.

In addition, to better understand the actual clinical usage patterns of anesthetic drugs, two directors of the department of anesthesiology from the sample hospital were interviewed using a semi-structured interview format, and preliminary data processing was conducted (The interview records are available as Supplementary Material 2). Based on the interview content and relevant guidelines [6,11-12], it was found that balanced anesthesia, namely the multimodal anesthesia is recommended. A combination of drugs is used during a single operation, and even drugs with the same

intended effect are often used together (e.g., the simultaneous use of two or more sedative-hypnotic drugs). A typical pattern is the combination of drugs that offer "rapid onset + long duration of action." Also, preliminary data analysis also showed that in a single general or local anesthesia procedure, each patient typically receives multiple anesthetic drugs with overlapping effects, further confirming the high prevalence of multimodal anesthetic use. Therefore, in addition to analyzing the use of individual drugs, this study also conducts a focused analysis of the following anesthetic regimens (Table 2):

(1) Local anesthesia regimen: Fixed combinations of local anesthetics that are commonly used in clinical practice and have been included in the centralized procurement program were selected for analysis.

(2) Drug regimens for general anesthesia (muscle relaxant): Regimens were extracted based on prescription records and focused on muscle relaxants included in the centralized procurement list.

Table 2. Regimens and corresponding drug combinations.

Regimen	Drugs
Drugs for General Anesthesia （Muscle Relaxants）	Cisatracurium Besylate Injection + Rocuronium Bromide Injection
Local Anesthetics	Lidocaine Hydrochloride Injection + Ropivacaine Hydrochloride Injection

To more comprehensively and objectively reflect the use of anesthetic drugs, this study further incorporates individual differences in patients' medical conditions and physical status by using two indicators: average dosage per procedure and usage rate. Given the unique nature of anesthetic drug use, dosages are often calculated and adjusted based on the patient's condition and physical characteristics [11], making it difficult to accurately determine a DDD. Therefore, this study adopts average dosage per procedure as the primary measurement indicator. At the same time, to quantitatively assess the use of individual drugs or drug regimens within the hospital, usage rate is included as a supplementary reference. The specific usage indicators are shown in the

193 Table 3.

194 **Table 3. Study Indicators.**

Indicator	Description	Calculation Formula
Average dosage per procedure	From January 1, 2019, the average dosage per procedure of each anesthetic drug (calculated weekly).	$\frac{\text{Number of times the drug was used}}{\text{Total amount used of a given drug in a week}}$
Proportion of use	The percentage of prescriptions containing a specific drug or drug combination during the study period (any prescription containing the specified drug or combination is counted as one use).	$\frac{\text{Number of prescriptions containing the drug during the study period}}{\text{Total number of prescriptions during the study period}} \times 100\%$

195 **2.3 Methods**

196 This study employed a multi-stage, comprehensive research design, beginning with
197 preliminary data processing and semi-structured interviews, followed by systematic
198 data analysis. First, basic statistical processing was conducted to establish the database.
199 Semi-structured interviews were then carried out with directors of the department of
200 anesthesiology in the sample hospital to understand the general patterns of clinical
201 anesthetic drug use (The interview records are available as Supplementary Material 2).
202 Based on this, propensity score matching (PSM) was applied to match and categorize
203 patients, aiming to improve comparability between groups before and after the
204 implementation of the NCDP. Finally, interrupted time series analysis (ITS) was
205 conducted on the processed sample to examine changes in average drug dosage per
206 procedure before and after policy implementation. In parallel, scatter plots with fitted
207 linear trend lines were used to track changes in the proportion of prescriptions
208 containing the drugs, allowing a comprehensive assessment of both key outcome
209 indicators. This approach further explored the impact of the NCDP policy on the use of
210 anesthetic drugs (Figure 2).

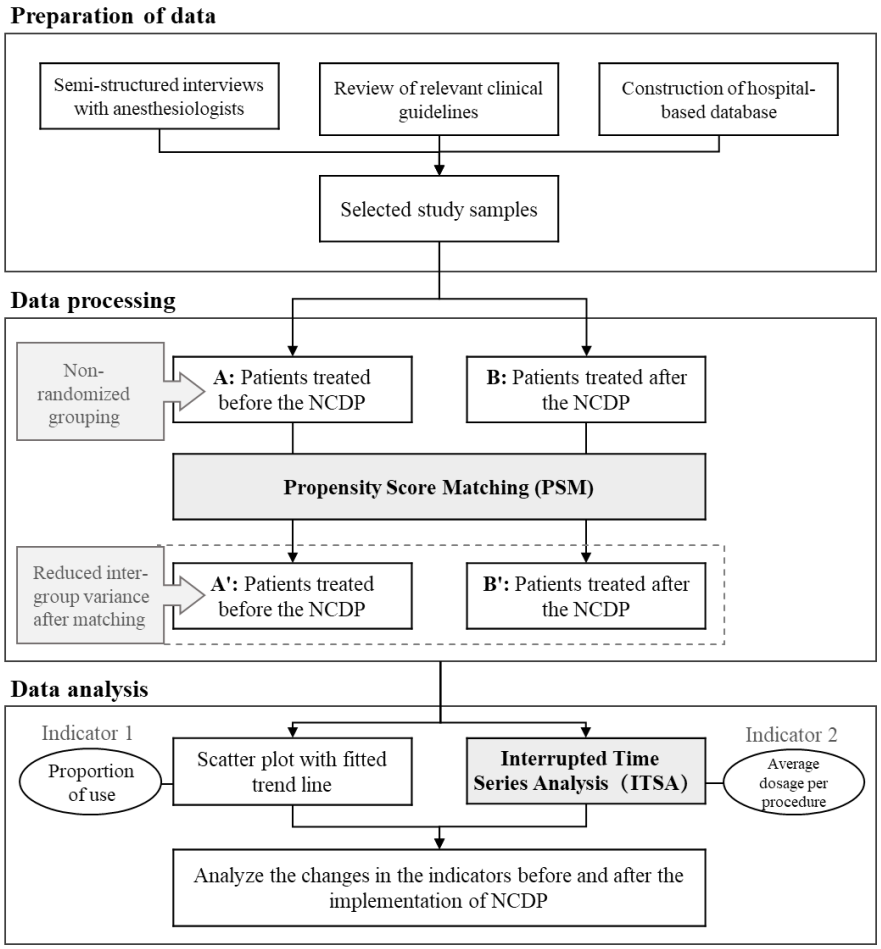


Figure 2. Study design and analytical framework.

2.3.1 Propensity Score Matching

Propensity Score Matching (PSM) is a non-experimental method used to estimate treatment effects. Its core idea is to achieve balance in covariates between the treatment group and the control group, under the condition of observed variables [14]. This helps reduce selection bias and eliminate confounding factors between groups. The method is commonly applied in fields such as medicine, public health, and economics. If a significant match is achieved, it can be assumed that there is no substantial baseline difference between the two groups.

In the data analysis for this study, patients who received a certain anesthetic drug or drug regimens are considered as a single study group (eg. The patients treated with Ropivacaine Hydrochloride Injection are considered as a study group). Based on the time of their hospital visits, this group is divided into a pre-procurement group and a

post-procurement group, using this as the binary treatment variable. To ensure high matching quality and minimize sample loss, the study uses the following individual-level covariates for each drug or drug regimen: age, gender, disease diagnosis type, and department of admission. A 1:2 nearest-neighbor matching within caliper method is applied, with a caliper value set at 0.01 [15].

2.3.2 Interrupted Time Series Analysis

Interrupted Time Series analysis is a statistical method used to analyze time-sequenced data to determine whether a specific intervention has led to a change. It is commonly used in the evaluation of health policies. ITS works by assessing changes in both the level and trend of outcome indicators before and after the intervention, allowing researchers to measure not only immediate effects but also long-term trends [16].

Based on these characteristics, this study applies the ITS method to analyze the data from the sample hospital between January 1, 2019, and March 30, 2025. The centralized procurement implementation date for the province of the sample hospital is treated as the intervention point. The period from January 1, 2019 to the implementation date is defined as pre-procurement, while the period from the implementation date to March 30, 2025 is considered post-procurement. The independent variable is time (weeks), and the dependent variable is the average dosage per procedure. The ITS model is specified as:

$$Y_t = \beta_0 + \beta_1 T + \beta_2 D + \beta_3 TD + \varepsilon_t$$

Y_t is the dependent variable, representing the outcome indicator at time t; T is the continuous time variable starting from the first week of the study period (January 1, 2019), with values 1, 2, 3, ..., n; D is a binary variable indicating whether centralized procurement has been implemented (0 for pre-procurement, 1 for post-procurement); TD captures the weekly trend after the policy implementation. β_0 represents the baseline level of the indicator, β_1 is the pre-procurement trend (slope), β_2 reflects the immediate effect after policy implementation, β_3 represents the post-procurement trend change,

indicating the long-term trend [17].

Moreover, because the study spans a long period, post-procurement long-term trends may shift. For drugs included in the fifth batch of centralized procurement, which have had longer implementation times, a dual-intervention ITS model is used. In addition to the initial procurement implementation date, a second intervention point is set at a year post-implementation. Thus, the period from implementation to the first anniversary is the short-term post-procurement period, and the period from the first anniversary to March 30, 2025 is the long-term post-procurement period. Week 53 marks the one-year point after implementation. The dual-intervention ITS model is specified as:

$$Y_t = \beta_0 + \beta_1 T + \beta_2 D_1 + \beta_3 (T-0) D_1 + \beta_4 D_2 + \beta_5 (T-53) D_2 + \varepsilon_t$$

In this model, the Y_t, T, β_0 and β_1 share the same meanings as the former model, while D_1 is a binary variable indicating whether procurement has been implemented (0 for pre-procurement, 1 for $0 \leqslant T < 53$); D_2 is a binary variable indicating whether one year has passed since implementation (0 for $T < 53$, 1 for $T \geqslant 53$); $(T-0)D_1$ captures the short-term trend post-implementation; $(T-53)D_2$ captures the long-term trend post-implementation. β_2 is the immediate change following procurement; β_3 is the short-term slope change; β_4 captures the immediate change after one year; β_5 represents the long-term trend change post-procurement.

For data handling, Microsoft Excel 2019 was used to build the database. Statistical analyses were performed through Stata 18.0. A two-sided p-value<0.05 was considered statistically significant.

3 Results

This study first conducted propensity score matching (PSM) for drugs and the regimens. For single drugs, matching was based on whether they were included in centralized procurement during the study period. For regimens, a grouping matching method was employed, with the outcome indicator being the average dosage per procedure. The matching results showed that both single drugs and regimens exhibited

significant treatment effects after PSM, and the absolute value of the standardized mean difference (SMD) of individual characteristics post-matching was below 10%, indicating an ideal matching effect.

Moreover, the sample loss after PSM was minimal, at less than 1%. This phenomenon could be attributed to two main reasons: (1) There were small baseline differences between groups [18]. The data for this study came from a single hospital, and patients were highly similar in terms of regional distribution, insurance type, and medical behaviors. Additionally, the decision-making processes of doctors, admission procedures and prescribing habits remained relatively stable, leading to a high degree of homogeneity between groups; (2) There was an adequate sample size and a reasonable matching strategy [19]. Although this study set a relatively strict caliper value, a 1:2 nearest neighbor matching approach was used to achieve a more balanced matching ratio, thereby reducing sample loss.

Due to space limitations, detailed results of the PSM will be presented in the appendix.

3.1 General anesthesia (Muscle relaxants)

Based on the preliminary data processing results, the use of muscle relaxants mainly includes the use of Cisatracurium Besylate Injection alone, Rocuronium Bromide Injection alone, and the combination of Cisatracurium Besylate Injection and Rocuronium Bromide Injection. This study will detail the results of the single drug and the muscle relaxant regimen separately (Table 4).

Table 4. Average Usage Rate of Muscle Relaxant Regimens.

Usage Situation	Medication Regimen	Round of NCDP (Implementation date)	Proportion
Single drug	Cisatracurium Besylate Injection	5th round (Oct 25, 2021)	20.07%
	Rocuronium Bromide Injection	7th round (Nov 25, 2022)	2.75%
Muscle relaxant regimen	Cisatracurium Besylate Injection + Rocuronium Bromide Injection	-	0.76%

3.1.1 Cisatracurium Besylate Injection

For the average dosage of Cisatracurium Besylate Injection, the ITSA was conducted using the date of implementation for the fifth round of centralized procurement (Oct 25, 2021, week = 0) as the intervention point. The results (Figure 3) showed an immediate but non-significant increase in drug usage ($\beta_2 = 1.779$, $P = 0.105$) following the fifth round of centralized procurement, while subsequent trend changes indicated a gradual increase in average dosage, though not significant ($\beta_3 = 0.0497$, $P = 0.127$).

One year after the implementation of centralized procurement, there was a immediate decrease in average dosage ($\beta_4 = -1.676$, $P = 0.139$), and the trend change was significantly negative ($\beta_5 = -0.087$, $P = 0.007$), indicating that after one year of implementation, the average dosage decreased at a rate of 0.090 units per week and gradually stabilized.

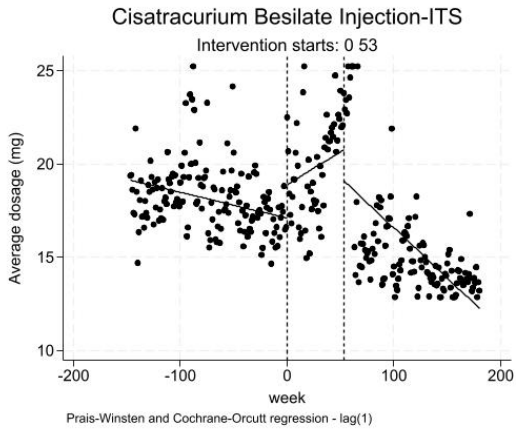


Figure 3. ITS of average dosage per procedure of Cisatracurium Besylate Injection.

In terms of proportion of use, the average usage rate of Cisatracurium Besylate Injection had a temporary decrease shortly after the centralized procurement intervention, followed by a long-term stabilizing trend. A month before the centralized procurement, the average usage rate was 21.04%, while the instantaneous average usage rate was 25.47% after procurement, dropping to 18.66% one year later. Overall, Cisatracurium Besylate Injection experienced slight fluctuations in average dosage and

proportion after centralized procurement, returning to pre-procurement levels and stabilizing over time (Figure 4).

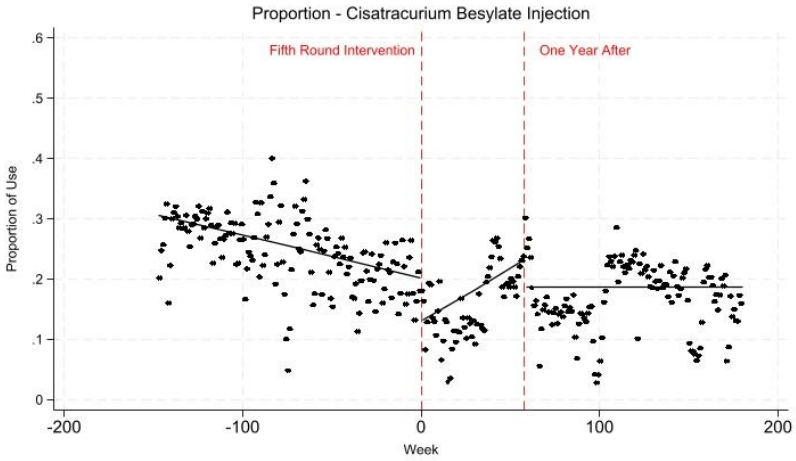


Figure 4. Proportion of use of Cisatracurium Besylate Injection.

3.1.2 Rocuronium Bromide Injection

For Rocuronium Bromide Injection, the ITSA was conducted with the date of implementation for the seventh round of centralized procurement (Nov 25, 2022, week = 0) as the intervention point. After the seventh round of centralized procurement, there was a non-significant decrease in average dosage (P = 0.269), and no significant trend was observed (P = 0.199), indicating a stable overall trend post-procurement (Figure 5).

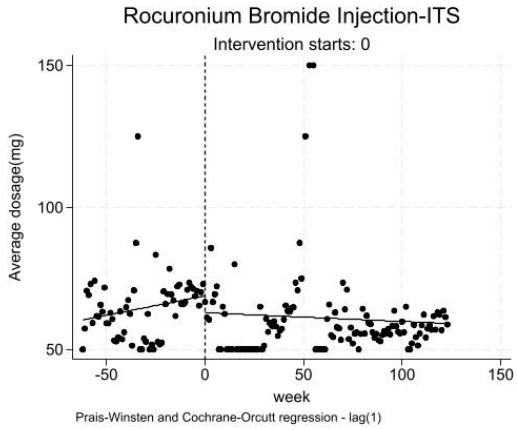


Figure 5. ITS of average dosage per procedure of Rocuronium Bromide Injection.

For proportion of use, a month before the seventh round of centralized procurement, the usage proportion of Rocuronium Bromide Injection remained stable at an average

proportion of 4.23%, with minimal fluctuations. After the intervention, there was no significant change in instantaneous proportion, followed by a noticeable increase that quickly fell back, with an average proportion of 10.5%. One year after the intervention, the proportion briefly rose before stabilizing with an average proportion of 6.67% (Figure 6).

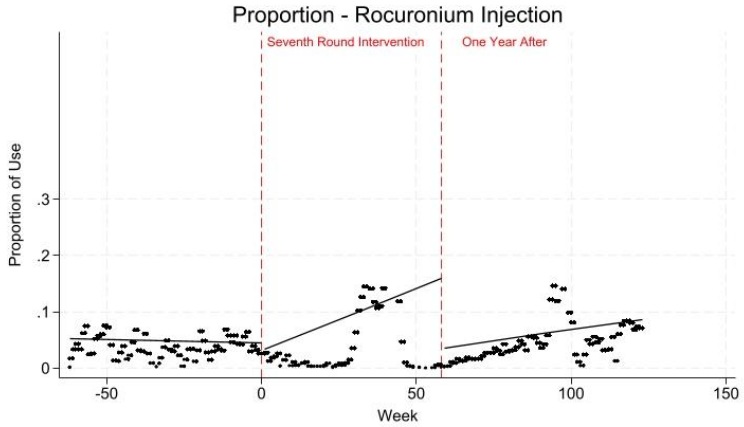


Figure 6. Proportion of use of Rocuronium Bromide Injection.

3.1.3 Drug Regimen for General anesthesia: Cisatracurium Besylate Injection and Rocuronium Bromide Injection

In this study, the muscle relaxant regimen refers to prescriptions that include both Cisatracurium Besylate Injection and Rocuronium Bromide Injection. Since Rocuronium Bromide Injection was first used in the sample hospital on September 20, 2021, just five weeks before the implementation of the fifth round of centralized procurement on October 25, 2021, using this procurement date as the intervention point would result in a very limited number of patients in the pre-procurement group. This would make accurate PSM difficult and reduce the robustness of the matching results. Therefore, for the muscle relaxant regimen, this study adopts the implementation date of the seventh round of centralized procurement—November 25, 2022—as the PSM intervention point.

After PSM was conducted, the ITSA was performed as follows: For Cisatracurium Besylate Injection, two intervention points were used: its own centralized procurement

date (Oct 25, 2021; week = 0) and the procurement date of its combination drug (Nov 25, 2022; week = 63). For Rocuronium Bromide Injection, its own procurement date (Nov 25, 2022; week = 0) served as the intervention point.

Both the average dosages of the drugs are varied right after the NCDP. The average dosage of Cisatracurium Besylate Injection showed a significant immediate decrease after the seventh round of centralized procurement (when Rocuronium Bromide Injection was centralized). However, the subsequent trend indicated a smoother decrease at a rate of 0.2 units per week (β_4 = -14.58, P = 0.000; β_5 = -0.20, P = 0.000); at this point, the average dosage of Rocuronium Bromide Injection also showed a significant immediate decrease (β_2 = -13.749, P = 0.000), and the usage trend shifted to a decline (β_3 = -0.375, P = 0.000), but the overall downward trend remained mild (Figure 7).

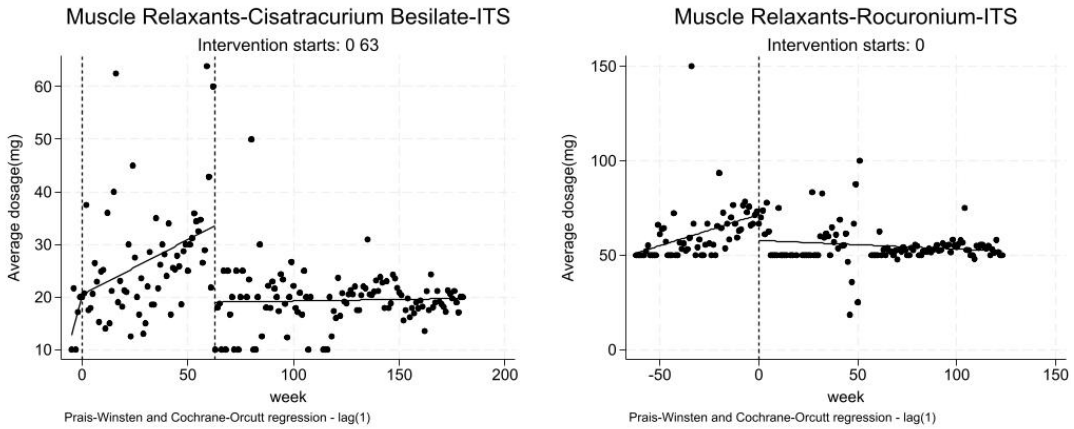


Figure 7. ITS of Average Dosage Per Procedure of Dual-Drug Combination Regimen of Muscle Relaxants.

For proportion of use, the proportion of the dual muscle relaxant regimen remained at about 1.7% after the implementation of the fifth round of centralized procurement, showing a slight reduction after the seventh round of centralized procurement, but without significant changes (Figure 8).

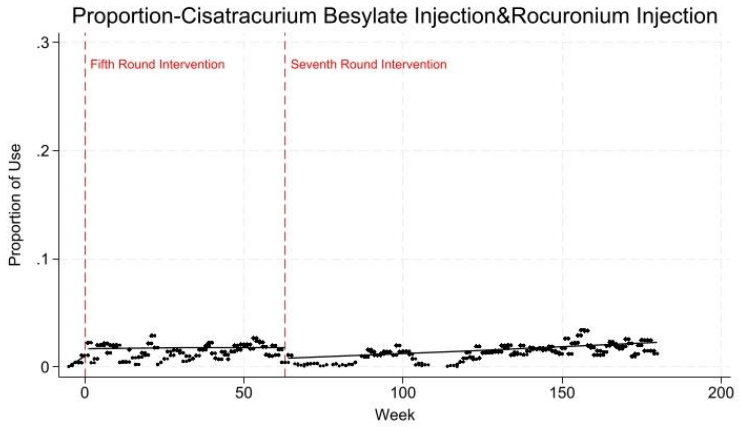


Figure 8. Proportion of use of Dual-Drug Combination Regimen of Muscle Relaxants.

The results of the study showed that, in terms of single drug, the instantaneous dosage and proportion of the regimen fluctuated significantly after the centralized procurement. One year after the 5th round of centralized procurement, the dosage and utilization rate of muscle relaxants gradually stabilized and returned to the pre-procurement levels. This indicates that as time goes by, doctors have gradually accumulated experience in using the centrally procured drugs and their recognition of the efficacy of these drugs has improved, thus leading to a gradual stabilization of dosage and a recovery in utilization rate.

In the regimen, although the dosage of Cisatracurium Besylate Injection decreased instantaneously after the centralized procurement of Rocuronium, it generally remained stable; the dosage of Rocuronium Bromide Injection also decreased slightly instantaneously after its centralized procurement, but remained stable afterwards; at the same time, the utilization rate of the combination therapy basically remained at around 1.7% without significant changes.

3.2 Local anesthesia

According to the preliminary data processing results, the local anesthesia regimens include Lidocaine Hydrochloride Injection alone, Ropivacaine Hydrochloride Injection alone, and the combination of the two drugs. This study will describe the results of the single drug and the dual-drug regimen separately (Table 5).

Table 5. Average Proportion of use of Local Anesthetic Regimens.

Usage Situation	Medication Regimen	Round of NCDP (Implementation date)	Proportion
Single drug	Lidocaine Hydrochloride Injection	7th round (2022.11.25)	70.31%
	Ropivacaine Hydrochloride Injection	5th round (2021.10.25)	23.58%
Local anesthesia regimen	Lidocaine Hydrochloride Injection + Ropivacaine Hydrochloride Injection	-	24.73%

3.2.1 Lidocaine Hydrochloride Injection

For the single use of Lidocaine Hydrochloride Injection, an ITS analysis was conducted with the date of implementation for the seventh round of centralized procurement (Nov 25, 2022, week=0) as the intervention point. Before the seventh round of centralized procurement, the average dosage of Lidocaine Hydrochloride Injection showed an overall downward trend, with a significant decrease of 0.207 units per period before the policy implementation (β_1 = -0.207, P = 0.000).

After the seventh round of centralized procurement, there was a significant immediate increase in the average dosage of Lidocaine Hydrochloride Injection (β_2 = 22.468, P = 0.016), followed by a subsequent increase of 0.333 units per month (β_3 = 0.333, P = 0.006). While there is an overall upward trend, the dosage gradually stabilizes post-procurement (Figure 9).

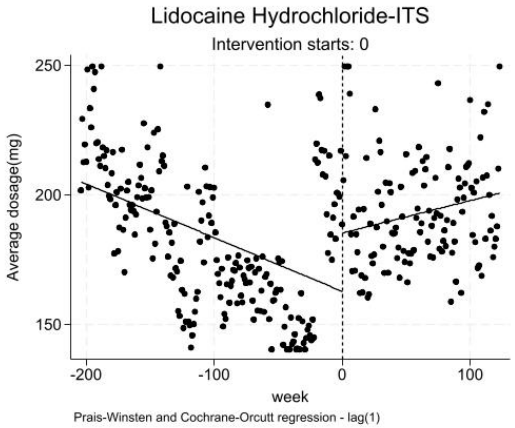


Figure 9. ITS of Lidocaine Hydrochloride Injection.

In terms of proportion of use, the proportion of Lidocaine fluctuated significantly before centralized procurement. A month before the centralized procurement, the average Proportion of use is 49.43%; after procurement, the average proportion was 50.26%, and the proportion became more stable post-procurement. One year after the procurement, the trend in proportion remained similar to within the year following procurement, with no significant fluctuations (Figure 10).

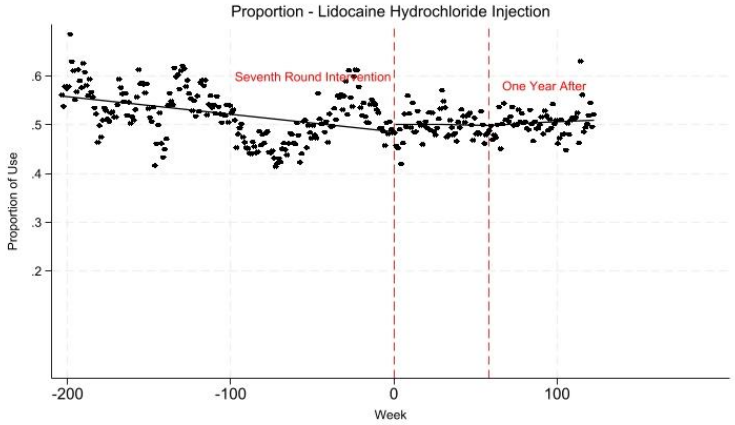


Figure 10. Proportion of use of Lidocaine Hydrochloride Injection

3.2.2 Ropivacaine Hydrochloride Injection

An ITSA was conducted with the date of implementation for the fifth round of centralized procurement (Oct 25, 2021) as the intervention point. Before the intervention, the trend of Ropivacaine was relatively stable (P = 0.666), indicating that the usage was stable prior to the intervention. After the fifth round of centralized procurement, the average dosage of Ropivacaine showed a non-significant immediate increase (P = 0.952) but exhibited a significant increasing trend, increasing by an average of 1.369 units per week. One year after procurement, the average dosage experienced a significant immediate decrease (β_4 = -20.090, P = 0.005), with a significant downward trend (β_5 = -1.639, P = 0.000). Despite a generally stable trend, the average dosage increased after the implementation of centralized procurement. (Figure 11).

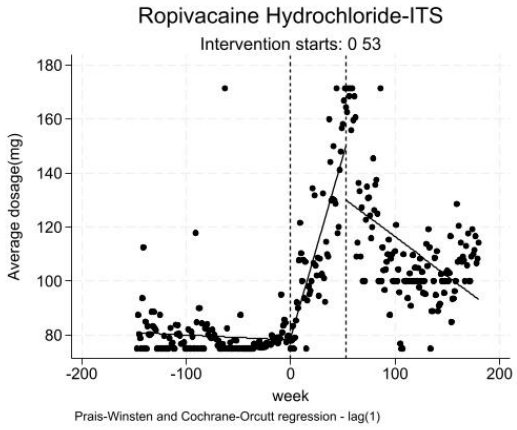


Figure 11. ITS of Ropivacaine Hydrochloride Injection.

For proportion of use, before the implementation of the 5th round of centralized procurement, the utilization rate of Ropivacaine showed a gradually increasing trend with fluctuations, with an average utilization rate of 9.82%. After the centralized procurement, the proportion dropped to 7.47% and rose again at about the 40th week. One year after the centralized procurement (at week 53, and the 7th round of centralized procurement was implemented at week 63), the dosage gradually stabilized and dropped back to 4.05% (Figure 12).

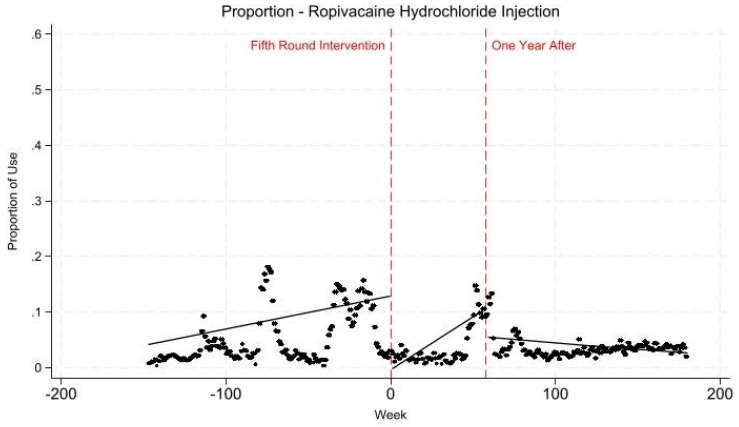


Figure 12. Proportion of use of Ropivacaine Hydrochloride Injection.

3.2.3 Local Anesthesia Regimens: Lidocaine Hydrochloride Injection and Ropivacaine Hydrochloride Injection

In this study, the local anesthesia regimen refers to a regimen that includes both Lidocaine Hydrochloride Injection and Ropivacaine Hydrochloride Injection in the

prescription. Due to the different implementation times of the centralized procurement of the two drugs, there are multiple intervention points, and PSM can only be used for two-group matching. Therefore, for the average dosage per procedure of the regimen, this study adopted two PSM matchings and conducted ITSA respectively: firstly, with the implementation time of the 5th round of centralized procurement (Oct 25, 2021, week=0, Ropivacaine was included) as the intervention point, and the average dosage per time of Ropivacaine Hydrochloride Injection as the outcome indicator (Appendix 6). After retaining the matched samples, ITS analysis was performed on the average dosage of Lidocaine and Ropivacaine respectively, using the 5th round and the 7th round as the intervention points; secondly, with the implementation time of the 7th round of centralized procurement (Nov 25, 2022, week=63, Lidocaine was included) as the intervention point, and the average dosage per time of Lidocaine Hydrochloride Injection as the outcome indicator, and the subsequent ITS plan was the same as the first time.

After the implementation of the 5th round of centralized procurement, the average dosage per procedure of Ropivacaine Hydrochloride Injection increased immediately by 12.73 units (β_2 = 12.731, P = 0.021), followed by a significant upward trend over time (β_3 = 1.312, P = 0.000). In contrast, Lidocaine Hydrochloride Injection showed no significant immediate change (P = 0.765), but also exhibited a significant upward trend in subsequent use (β_3 = 3.705, P = 0.000). Following the 7th round of centralized procurement, the average dosage per procedure of Ropivacaine Hydrochloride Injection declined significantly (β_4 = -58.690, P = 0.000), with a subsequent overall downward trend (β_5 = -1.374, P = 0.000). During the same period, Lidocaine Hydrochloride Injection also experienced a significant immediate reduction in average dosage per procedure (β_2 = -61.312, P = 0.015), though its short-term trend was not statistically significant (P = 0.703) (Figure 13).

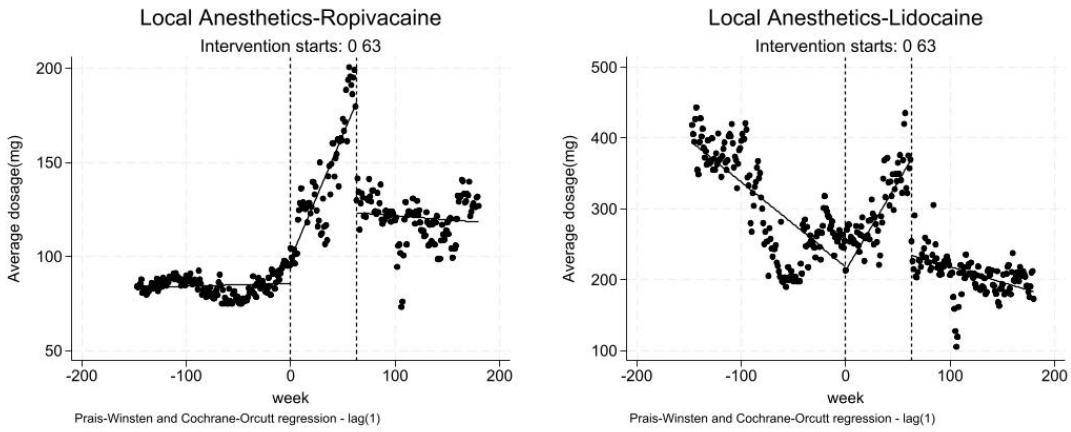


Figure 13. ITS of average dosage per procedure of the local anesthesia regimen after the first PSM (Intervention point: the 5th round centralized procurement).

The ITS results after the second PSM were generally consistent with those of the first analysis. Following the 5th round of centralized procurement, the average dosage per procedure of Ropivacaine Hydrochloride Injection increased immediately by 12.75 units ($\beta_2 = 12.752$, $P = 0.021$), accompanied by a significant upward trend thereafter ($\beta_3 = 1.313$, $P = 0.000$). During the same period, Lidocaine Hydrochloride Injection showed no significant immediate change ($\beta_2 = -5.992$, $P = 0.768$), but its dosage per procedure also exhibited a marked upward trend over time ($\beta_3 = 3.696$, $P = 0.000$). After the 7th round of centralized procurement—when the co-administered drug Lidocaine Hydrochloride Injection was included—the average dosage per procedure of Ropivacaine Hydrochloride Injection declined significantly ($\beta_4 = -58.651$, $P = 0.000$), followed by a slight but significant downward trend ($\beta_5 = -1.370$, $P = 0.000$). Meanwhile, Lidocaine Hydrochloride Injection also showed a significant immediate decrease ($\beta_2 = -61.344$, $P = 0.014$), with a subsequent trend that remained largely stable ($P = 0.702$) (Figure 14).

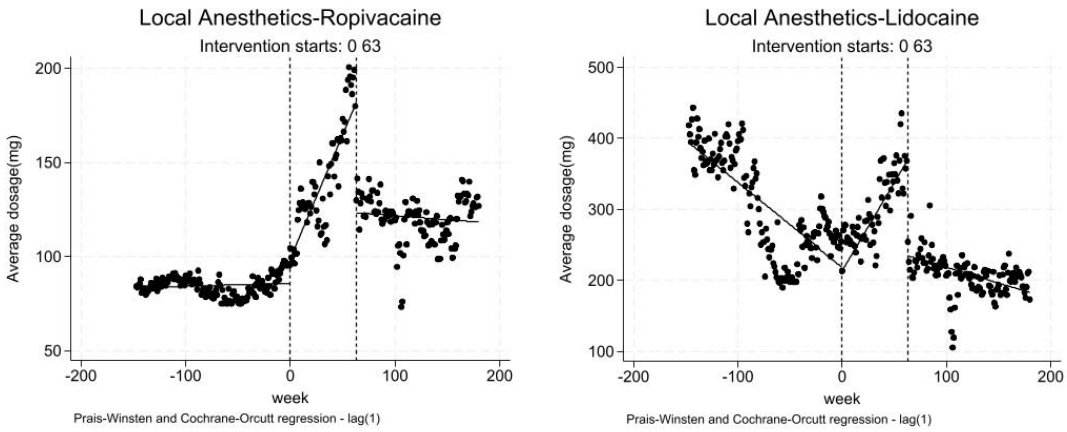


Figure 14. ITS of average dosage per procedure of the local anesthesia regimen after the first PSM (Intervention point: the 7th round centralized procurement).

In terms of proportion of use, before the implementation of the 5th round of centralized procurement, the combination ratio of Lidocaine and Ropivacaine showed an overall downward trend. In the short term after the implementation of the 5th round of centralized procurement, the combination ratio dropped rapidly and remained at a low level (with an average of about 17.86%), but the utilization rate showed a slow recovery afterwards; after the implementation of the 7th round of centralized procurement, the utilization rate was generally stable, with an average of about 23.39%, showing a slight upward trend. Overall, after the implementation of the two roundes of centralized procurement, the combination use of drugs showed a stable trend with a slight increase (Figure 15).

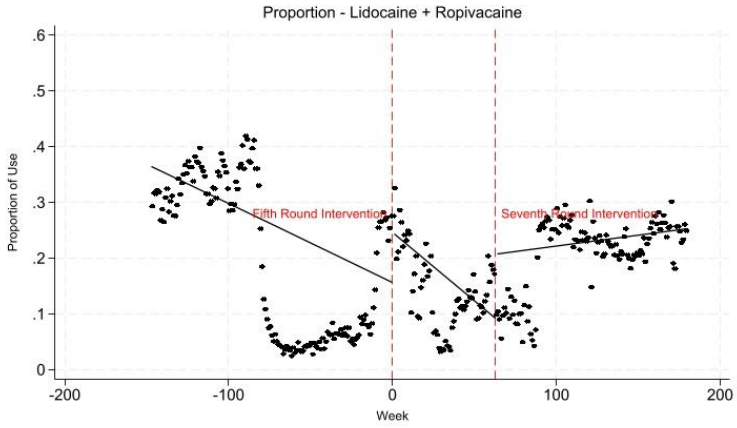


Figure 15. Proportion of use of Dual-Drug Combination Regimen of Local Anesthetics.

From the perspective of single drug, local anesthetics also showed significant

fluctuations in dosage and utilization rate after the implementation of centralized procurement, but the overall trend stabilized one year after the procurement. Compared with muscle relaxants, the average dosage per time of Lidocaine Hydrochloride Injection and Ropivacaine Hydrochloride Injection fluctuated more greatly. Although there were increases and decreases, they were always within the range specified in the instruction manual, and the drug use was still reasonable. One year after the centralized procurement, the dosage and utilization rate of these two local anesthetics both returned to the pre-procurement levels, and their changing trends were similar to those of the aforementioned muscle relaxants.

In terms of regimen, Ropivacaine Hydrochloride Injection was included in the centralized procurement earlier, resulting in a significant increase in both its immediate average dosage per procedure and the subsequent usage trend. At that time, Lidocaine Hydrochloride Injection had not yet been included in centralized procurement, showing no immediate change but a notable upward trend in usage over time. After Lidocaine Hydrochloride Injection was included in centralized procurement, the average dosage per procedure of both drugs showed a temporary decline, followed by a stable trend. Regarding the proportion, the proportion of Ropivacaine Hydrochloride Injection rose sharply in the short term after its inclusion in centralized procurement and then gradually declined. Following the centralized procurement inclusion of Lidocaine Hydrochloride Injection, its combination rate also experienced a brief increase before stabilizing.

Given the differences in their duration of action, the two drugs are not considered therapeutically interchangeable. After the fifth round of centralized procurement, both drugs showed a concurrent increase in dosage and a decline in proportion, possibly reflecting physicians' concerns about the efficacy of the Ropivacaine, prompting increased dosage and reduced proportion. Following the seventh centralized procurement round, both drugs witnessed a decrease in dosage and an increase in combination rate, with trends stabilizing overall; however, Ropivacaine's dosage

remained higher than pre-procurement levels. These patterns suggest that clinicians may adopt precautionary adjustments in response to such products.

4 Discussion

4.1 Post-procurement usage of anesthetic drugs shows a pattern of "short-term fluctuation, long-term stabilization."

Based on the findings above, both the average dosage per procedure and proportion of anesthetic drugs showed short-term fluctuations and a return to stable long-term trends after the implementation of centralized procurement. This pattern is primarily attributed to two main factors:

First, after the hospital replaced more than 70% of its anesthetic inventory with centrally procured drugs from winning manufacturers, physicians initially adopted a cautious approach toward the use of new brands and formulations. According to related studies [20], doctors stated that when first using drugs from newly contracted manufacturers, they would sometimes adjust dosages within the range specified in the drug label or combine them with other medications to ensure the effectiveness of the procured brand. For example, the average dosage per procedure of Lidocaine Hydrochloride Injection and Ropivacaine Hydrochloride Injection increased after procurement, but the increase remained within the recommended dosage ranges stated in the drug label (Table 6). Additionally, the proportion of use of the local anesthetics regimen increased in the short term, indicating a greater tendency for multimodal drug use immediately following procurement.

Table 6. Recommended dosage for local anesthetics (from drug labels).

Drug name	Recommended dosage (mg)
Lidocaine Hydrochloride Injection	50~300
Ropivacaine Hydrochloride Injection	7.5~225
Recommended dosage refers to the minimum and maximum dose range used for surgical anesthesia.	

As time progressed, with doctors gaining more clinical experience and increased

confidence in the effectiveness of the drugs, they became more proficient in administering the medications, and the dosage levels gradually returned to pre-procurement levels. Changes in proportion further confirmed that doctors initially adopted a cautious attitude toward the centrally procured drugs. In the short term, the proportion of some drugs declined after procurement. However, one year after implementation, proportion gradually returned to pre-procurement levels. This suggests that in the early phase, physicians limited the use of newly procured drugs. But over time, as they gained familiarity and recognized the drugs' effectiveness through clinical use, the proportion increased again.

Second, the observed pattern is also due to the policy effect of centralized procurement itself. The policy significantly lowered drug prices, encouraging physicians to prioritize lower-cost drugs when making prescribing decisions based on patient needs. Existing research has shown that centralized procurement effectively reduces drug prices and alleviates the financial burden of medication for patients [20-22]. Also, a study concerning prescription behavior indicates that physicians tend to prescribe centrally procured drugs with lower prices for most patients [23], suggesting that the price advantage brought about by the policy influences physicians' prescription behavior, which in turn affects the overall proportion of these drugs.

4.2 No structural changes in clinical anesthetic drug use following centralized procurement.

At the same time, the study results show that the proportion of anesthetic drugs and their multimodal drug combinations did not experience significant fluctuations. In some cases, the combination rates remained stable in the long term after the centralized procurement intervention. These findings indicate that the policy did not substantially alter the actual clinical structure of anesthetic drug use. The public concern about "anesthetics that don't anesthetize" was not observed in this study.

From the perspective of drug characteristics, existing studies suggest that perioperative drug management in anesthesiology is highly standardized, and

physicians tend to adopt conservative approaches to intraoperative medication [24]. As a result, clinical practice is less influenced by external policy changes. Additionally, interview records (Supplementary Material 2, line 150-160) suggest that although drugs within the same class of anesthetic drugs may share similar mechanisms of action, they often differ significantly in terms of onset time and duration of action [12], making them largely non-interchangeable. Therefore, the impact of policy adjustments on actual clinical use remains limited [25].

From the perspective of physician behavior, the main mechanism of the centralized procurement policy is cost containment through price reduction. However, its effect on changing doctors' prescribing habits and medication choices has been relatively limited [26]. This is one of the key reasons why no significant structural change in clinical anesthetic use was observed after the implementation of procurement.

5 Conclusion

This study shows that the implementation of NCDP had a noticeable short-term effect on the use of anesthetic drugs, primarily reflected in temporary fluctuations in dosage and proportion for certain drugs. However, in terms of long-term trends, the overall impact of the policy on anesthetic drug use has been limited, and no substantial changes have occurred in clinical anesthesia regimens. From the perspective of dosage, there is no evidence to support concerns about "anesthetics that don't anesthetize" despite the price cut.

Moreover, the findings indicate that anesthetic drug use is largely driven by physicians' autonomous clinical decision-making. These decisions are influenced by a combination of behavioral motivations, psychological perceptions, and policy environment factors. This complex mechanism calls for systematic analysis using multi-center empirical data and the continuous improvement and innovation of relevant theoretical models.

However, the study has two key limitations. First, the data are limited in scope. The analysis is based on a single hospital, with a relatively small sample size, and does not

include usage patterns from other regions or medical institutions. As such, the representativeness of the results is limited, and the findings may not reflect national trends in anesthetic drug use. Broader, multi-center studies are needed to validate these conclusions.

Second, the study adopts a single-dimensional perspective. It mainly focuses on changes in drug usage volume, without evaluating clinical effectiveness or examining how drug use may impact patient outcomes. Without evidence from the perspective of therapeutic efficacy, the conclusions about anesthetic drug use may be biased and cannot fully reflect the appropriateness and effectiveness of clinical decisions.

6 List of abbreviations

For clarity, all abbreviations appearing in this study are listed in Table 7.

Table 7. Abbreviations.

Abbreviation	Full Name
NCDP	National Centralized Drug Procurement Policy
DDD	Defined Daily Dose
PSM	Propensity Score Matching
ITS	Interrupted Time Series

7 Declarations

Ethics approval and consent to participate

All research on human subjects was approved by the ethics committee of China Pharmaceutical University and Anqing Municipal Hospital, which deemed that our research did not involve intervention measures, and therefore granted a waiver for informed consent forms. The use of the data conformed to the principles outlined in the Declaration of Helsinki.

Consent for publication

Not applicable.

Availability of data and materials

Data are available from the authors upon reasonable request and with permission of Anqing Municipal Hospital.

Competing interests

The authors declare no conflict of interest.

Funding

This study was supported by the National Natural Science Foundation of China (#72404281) and the 2025 Innovation and Entrepreneurship Training Program for College Students at China Pharmaceutical University (No.280).

Authors' contributions

Yuxin Xiao and Fanyu Lin analyzed data and wrote the main manuscript. Runbo Zhu, Xinyu Wang, and Yichen Liu helped analyzing data. Wei Li and Lijuan Huang reviewed manuscripts and made suggestions. All authors reviewed the manuscript.

Acknowledgements

Not applicable.

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