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DRG payment for male reproductive system malignant tumor surgery: analysis and recommendations on resource consumption in a tertiary hospital in China

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Abstract

Aim This study aimed to examine the consistency of resource consumption (cost homogeneity) and influencing factors of the diagnosis-related group (DRG) "major operations for malignant tumors of the male reproductive system with general complications or comorbidities" (MA13) and offer recommendations for improving the efficacy of the grouping.

Methods This retrospective study analyzed medical records and insurance settlement data of all MA13 patients admitted to a tertiary urology department from January 2021 to December 2024. Combined with semi-structured interviews with urologists, key clinical cost drivers were identified. Multiple linear regression analysis was utilized to assess the significance of these factors and their specific impact on various service costs. We provided recommendations for improving MA13 groupings and evaluated their effectiveness using the coefficient of variation (CV) and t-tests.

Results The CV for the MA13 group was 0.41. Age and robot-assisted surgery emerged as independent factors due to their statistically dominant effects ($P < 0.001$) in multivariate regression, whereas comorbidities and insurance type showed limited explanatory power (adjusted $R^2 = 0.72$). Subgrouping MA13 by age and robotics reduced intra-group heterogeneity (CV: 0.12–0.35 vs. 0.41), enabling equitable reimbursement for advanced surgical techniques while maintaining manageable DRG categories.

Conclusions Supplementary payments for robot-assisted surgery should be considered to ensure equitable access to advanced technologies while maintaining cost-effectiveness. Stratified validation methods are essential for evaluating grouping effectiveness, which can help improve intra-group consistency and facilitate a more equitable distribution of medical resources.

Keywords DRG, MA13, Semi-structured interview, Robot-assisted surgery, Coefficient of variation

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Introduction

China's healthcare sector has achieved significant milestones since its reform and opening-up policies, including a life expectancy of 79 years and universal health insurance coverage [1, 2]. However, rising healthcare demand and insurance expenditures have intensified systemic pressures. Historically, health insurance payment in China employed the traditional "fee-for-service" (FFS) model, which, while simple and manageable, resulted in over-treatment, imbalanced distribution of medical resources, and increasing medical expenses [3]. In addressing these concerns, China's healthcare reforms since 2019 have prioritized diagnosis-related group (DRG) payments to replace fee-for-service models, aiming to standardize clinical pathways and contain costs [4]. This system originated in the United States in the 1970s and is now widely utilized in Western countries [5]. Diagnosis-related groups (DRGs) classify hospitalized cases into clinically coherent categories based on diagnoses, age, comorbidities, and resource utilization, with predefined reimbursement rates for each group [6].

In China's CHS-DRG system, group homogeneity is evaluated through the coefficient of variation (CV) of hospitalization costs—a statistical measure of intra-group consistency. A CV threshold of < 1 is mandated to ensure stable payment standards [7]. However, challenges persist in oncology-related DRG categories, exemplified by the MA13 group ("major surgeries for male reproductive malignancies with comorbidities"). MA13 exhibits a CV of 0.41, exceeding institutional benchmarks due to the dominance of prostate cancer cases (95.8% of the cohort) requiring robot-assisted surgeries. These advanced techniques incur hospitalization costs substantially surpassing current DRG payment standards, creating financial disincentives for hospitals to adopt innovations and restricting equitable patient access to precision interventions. Globally, the prevalence and mortality rates of malignant tumors in the male reproductive system are increasing globally [8, 9]. The hospitalization costs for patients undergoing surgical treatment for these conditions are substantial, imposing a significant economic burden on patients and their families while complicating the efficient allocation of healthcare resources [10]. Therefore, there is an urgent need for more standardized and refined management of hospitalization expenses for patients undergoing surgery for malignant tumors of the male reproductive system.

Our study bridges a gap in DRG literature by focusing specifically on MA13, integrating clinician perspectives with quantitative analysis of its unique cost drivers, including age stratification (≥ 65 vs. <65 years) and robotic utilization. These findings directly inform targeted DRG refinements for MA13, balancing cost containment with equitable access to precision oncology interventions.

Methods

Study design and patients

The data were obtained from the medical records and insurance settlement information of all patients admitted to the MA13 group in the Department of Urology at our institution. The inclusion period extended from January 2021 to December 2024. The dataset included various specific information: age, length of stay (LOS), number of clinical visits, insurance type, robot-assisted surgery, comorbidities (hypertension and diabetes), RW, total hospitalization costs, and costs for each service category (drug costs, material costs, blood product costs, inspection costs, medical service costs, rehabilitation costs, and other costs), tumour-node-metastasis (TNM) stage (extracted from surgical pathology reports and clinical records), and additional critical clinical characteristics. Data underwent rigorous validation: (1) MA13 classification was verified against CHS-DRG grouper criteria; (2) outliers (e.g., LOS > 30 days due to unrelated complications) were excluded ($n = 12$); (3) costs exceeding ± 3 SDs from the mean ($n = 9$) were winsorized to mitigate skewness.

The MA13 group (CHS-DRG code: MA13) is defined as 'major surgeries for malignant tumors of male reproductive organs (e.g., prostate, testis, penis) with general complications or comorbidities (CCs)' in the CHS-DRG manual (version 1.1). Grouping criteria include principal diagnosis (ICD-10 codes: C60-C63), surgical procedures (e.g., radical prostatectomy, orchiectomy), and the presence of CCs (e.g., hypertension, diabetes) documented during hospitalization. This classification aligns with the CHS-DRG grouper logic, which prioritizes diagnosis, procedure complexity, and comorbidity burden.

The research protocol was approved by the Clinical Research Ethics Committee of the First Affiliated Hospital, College of Medicine, Zhejiang University (grant nos. IIT20241621A). The need for informed consent was waived due to the retrospective nature of the study. The study was conducted according to the national legislation and institutional guidelines.

Statistical analyses

The hospitalization costs for the MA13 group were described using the mean, extremes (minimum costs and maximum costs), and standard deviation (SD). The CV was calculated to describe the within-group homogeneity. Patients were dichotomized as "older" (≥ 65 years) or "non-older" (< 65 years). This threshold aligns with China's retirement age framework and geriatric surgery literature, where age ≥ 65 is commonly used to define heightened surgical risk and resource utilization. An

independent samples t-test with Welch's correction was conducted (t = -4.756, $P < 0.001$), revealing that the average hospitalization cost for patients aged 65 and above (48,362.98 CNY) was significantly higher than that for patients under 65 (45,272.07 CNY), with an absolute difference of 3,090.91 CNY (95% CI: -4,365.38 to -1,816.44), indicating a significant difference in medical costs between the two age groups.

A semi-structured interview was performed by doctors from the urology department of our hospital to identify clinical factors that may increase hospitalization costs for male patients undergoing surgery for malignant tumors of the reproductive system. To ensure confidentiality, all interviews were conducted anonymously, with participant identifiers removed prior to analysis. Interview transcripts underwent iterative thematic coding by two independent researchers, with discrepancies resolved through consensus discussions with senior urologists. This process enhanced the reliability of qualitative findings and minimized interpretive bias. The interview focused on three core issues: the applicability of the current grouping scheme for male reproductive system malignant tumor surgery patients, the justification of payment standards, and potential clinical factors leading to increased hospitalization costs. Neutrality was maintained during the interview, and responses were documented to extract essential information. The results revealed the frequency of mentions for each factor. Interview responses were analyzed via frequency coding, with factors ranked by mention rate. Themes were validated through iterative discussions with urologists.

To rigorously validate the stability of our model, we conducted stepwise regression analyses on the original seven variables. In the forward selection phase (entry $\alpha = 0.05$) and backward elimination (removal $\alpha = 0.10$), urban resident medical insurance (URMI) emerged as the sole non-significant variable ($P = 0.336$) in both selection processes. So we retained all seven variables in the final model. A sensitivity analysis further confirmed the robustness of our findings: when LOS and number of visits—variables potentially tautological with costs (e.g., prolonged stays directly increase room charges)—were excluded, the adjusted R^2 decreased from 0.88 to 0.84, yet age and robot-assisted surgery remained strongly significant ($P < 0.001$). This consistency across model specifications underscores their dominance in explaining cost variation. Given the right-skewed distribution of hospitalization costs, sensitivity analyses using log-transformed costs were conducted. Results were consistent with the primary model (adjusted $R^2 = 0.72$).

While TNM staging is not a direct component of CHS-DRG grouping, it was included to control for disease severity, which may indirectly influence resource utilization (e.g., prolonged operative time for advanced tumors). Although TNM staging exhibits inter-institutional variability, its inclusion aimed to isolate confounding effects of oncologic complexity on costs. We acknowledge this limitation and have interpreted its impact cautiously in the Discussion.

Multiple linear regression analysis was employed to identify the clinical factors that significantly influence total hospitalization costs and their impact across various service categories. Recommendations for enhanced grouping efficacy were subsequently proposed and validated through t-tests. Calculated variance inflation factors (VIF) for all variables, while VIFs < 3 indicated no severe collinearity. Statistical Package for the Social Sciences software (version 22.0) and R software (version 4.3.2) were used for all statistical analyses. A $P < 0.05$ was considered statistically significant.

Table 1 Costs information of MA13 in department of urology surgery in Author's institution

DRG group	MA13
Number of cases	5318
RW	2.62
Payment standard	55162.62
Average costs	47582.98
Min. costs	4888.36
Max. costs	109593.38
SD	19705.07
CV	0.41

***DRG**: Diagnosis-Related Groups;**RW**: relative weight;**SD**: standard deviation;**CV**: coefficient of variation. All costs are presented in Chinese Yuan (CNY)*

Results

Descriptive analysis of medical and insurance settlement data

The final analysis included data from 5,318 cases of MA13. The mean hospitalization cost for MA13 was 47,582.98 CNY, with a CV of 0.41 (Table 1). Table 2 presents the demographic and clinical characteristics of patients in the MA13 group, including age, LOS, number of clinical visits, insurance type, robot-assisted surgery, and comorbidities. The total hospitalization costs were classified into medical service, inspection, material, drug, blood product, others, and rehabilitation costs (from highest to lowest proportion). Table 3; Fig. 1 present the detailed costs for each category.

Semi-structured interview results

A semi-structured interview was conducted by 87 urology department doctors at our hospital; the interview was aimed at identifying key clinical factors that may influence hospitalization costs for male patients undergoing surgery for malignant tumors of the reproductive system. During the interview, 64 respondents indicated that the current grouping scheme for male reproductive

Table 2 Demographic and clinical characteristics of MA13 cases

Characteristics	Number of cases	Proportion (%)
Age (years)		
<65	1342	25.24
≥65	3976	74.76
LOS (days)		
≤7	3344	62.88
>7	1974	37.12
Number of clinical visits		
1	2229	41.91
2	2554	48.03
≥3	535	10.06
Insurance type		
full self-pay	597	11.23
URMI	2113	39.73
UEMI	2608	49.04
Robot-assisted surgery		
no	2500	47.01
yes	2818	52.99
Hypertension		
no	2919	54.89
yes	2399	45.11
Diabetes		
no	4457	83.81
yes	861	16.19
TNM		
I	958	18.01
II	3921	73.73
III	373	7.01
IV	66	1.24

***LOS**: length of stay;**URMI**: urban resident medical insurance;**UEMI**: urban employee medical insurance;**TNM**: tumour-node-metastasis*

Table 3 The costs information for each service category of MA13 patients

	Average costs	Min. costs	Max. costs	SD
Drug costs	5124.93	316.98	35723.70	2889.93
Material costs	5160.86	80.41	31879.10	1919.49
Blood product costs	721.53	0.00	12746.93	1423.75
Inspection costs	5285.00	1404.00	2627.00	1266.18
Medical service costs	30923.24	2049.20	65399.80	20022.38
Rehabilitation costs	78.44	0.00	739.00	145.26
Other costs	288.98	0.00	2820.95	413.89
Total cost	47582.98	4888.36	109593.38	19705.07

SD: *standard deviation. All costs are presented in Chinese Yuan (CNY)*

system malignant tumor surgery patients does not meet clinical practice needs, while 70 respondents noted that the current payment standards do not cover the surgery cost. Respondents frequently identified key clinical factors contributing to increased hospitalization costs, including robot-assisted surgery (87/87, 100%), LOS (81/87, 93.1%), older patients (72/87, 82.8%), diabetes (66/87, 75.9%), insurance type (62/87, 71.3%), hypertension (60/87, 69.0%), and number of clinical visits (55/87, 63.2%), listed in descending order (Fig. 2).

Multiple linear regression analyses of the cost-influencing factors

We utilized a multiple linear regression model to thoroughly analyze the impact of seven clinical factors on the total hospitalization costs of MA13 patients based on data from semi-structured interviews. These factors include age, LOS, number of clinical visits, insurance type, robot-assisted surgery, hypertension, and diabetes. VIF for all variables were < 3 (e.g., age: VIF = 1.03; robotics: VIF = 1.06), indicating no severe collinearity (Table 4). The results revealed that age and robot-assisted surgery significantly contributed to increased hospitalization costs ($P < 0.001$; Table 4). Patients with TNM stage III cancers incurred an additional 1,137.36 CNY ($P = 0.007$), while stage IV cases showed even higher incremental costs (2,867.91 CNY, $P = 0.001$) compared to stage I (Table 4). We addressed the multicollinearity issue to ensure the robustness of the model, which resulted in an adjusted $R^2 = 0.88$. A histogram analysis confirmed that the residuals approximately follow a normal distribution, further supporting the effectiveness and reliability of the model.

Further analysis was performed to evaluate the impact of age and robot-assisted surgery on the costs of seven service categories. The results revealed a significant increase in various expenses for older patients, with an average increase of 1,901.78 CNY in medical service costs and 451.34 CNY in material costs. Medical service costs increased significantly by 39,051.42 CNY for patients undergoing robot-assisted surgery, while drug costs decreased by 1,128.65 CNY (Fig. 3).

Proposal of subdividing group MA13 and its statistical validation

We selected patients undergoing robot-assisted surgery separately and used t-tests to examine the differences in hospitalization costs between these patients and other MA13 patients based on the analysis of the influencing factors mentioned above. The original MA13 group was divided into younger patients (< 65 years) with robot-assisted surgery (MA13a-R), older with robot-assisted surgery (MA13b-R), non-older without robot-assisted surgery (MA13a-NR), and older without robot-assisted surgery (MA13b-NR) to eliminate the confounding influence of age. The results indicated that older patients exhibited significantly higher hospitalization costs in the subgroup not undergoing robot-assisted surgery. The CVs of all four subgroups were lower than that of the original MA13 group. Two subgroups (MA13a-NR: ¥25,900.57; MA13b-NR: ¥29,246.07) had average costs significantly below the MA13 payment standard (¥55,162.62), whereas

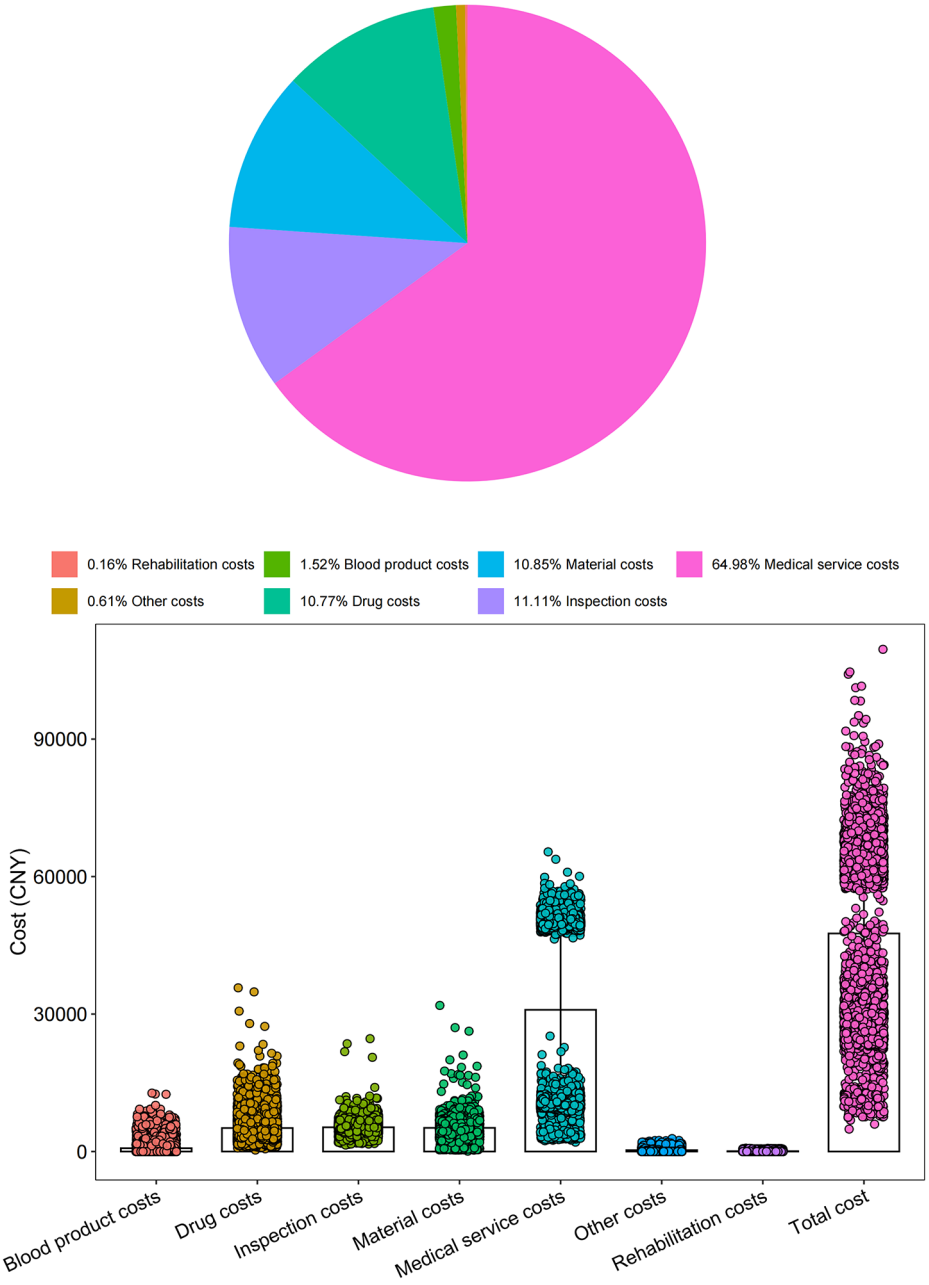

Fig. 1 Proportion of service categories and associated cost distribution among MA13 patients

the robotic subgroups (MA13a-R: ¥64,471.12; MA13b-R: ¥64,697.94) exceeded the standard by 17–17.3% (Table 5; Fig. 4).

Analysis of influencing factors of robot-assisted surgery

We examined the influencing factors of robot-assisted surgery. The multivariate logistic regression model revealed that older age (odds ratio [OR] = 1.137, 95% confidence interval [CI]: 1.004–1.288, $P = 0.043$, hypertension (OR = 1.198, 95% CI: 1.073–1.338, $P = 0.001$), and diabetes (OR = 1.394, 95% CI: 1.199–1.620, $P < 0.001$) were the influencing factors for robot-assisted surgery. Interestingly, patients with TNM stage II tumors were less likely to undergo robot-assisted surgery (OR = 0.851, 95% CI:0.738–0.982, $P = 0.027$), possibly reflecting clinicians' preference for conventional approaches in intermediate-risk cases. However, no significant association was observed for stages III or IV ($P > 0.05$), indicating disease severity alone does not dictate robotic utilization (Table 6). Despite higher upfront costs, robotics reduced drug expenses by ¥1,128.65 ($P < 0.001$), suggesting potential long-term savings from fewer complications.

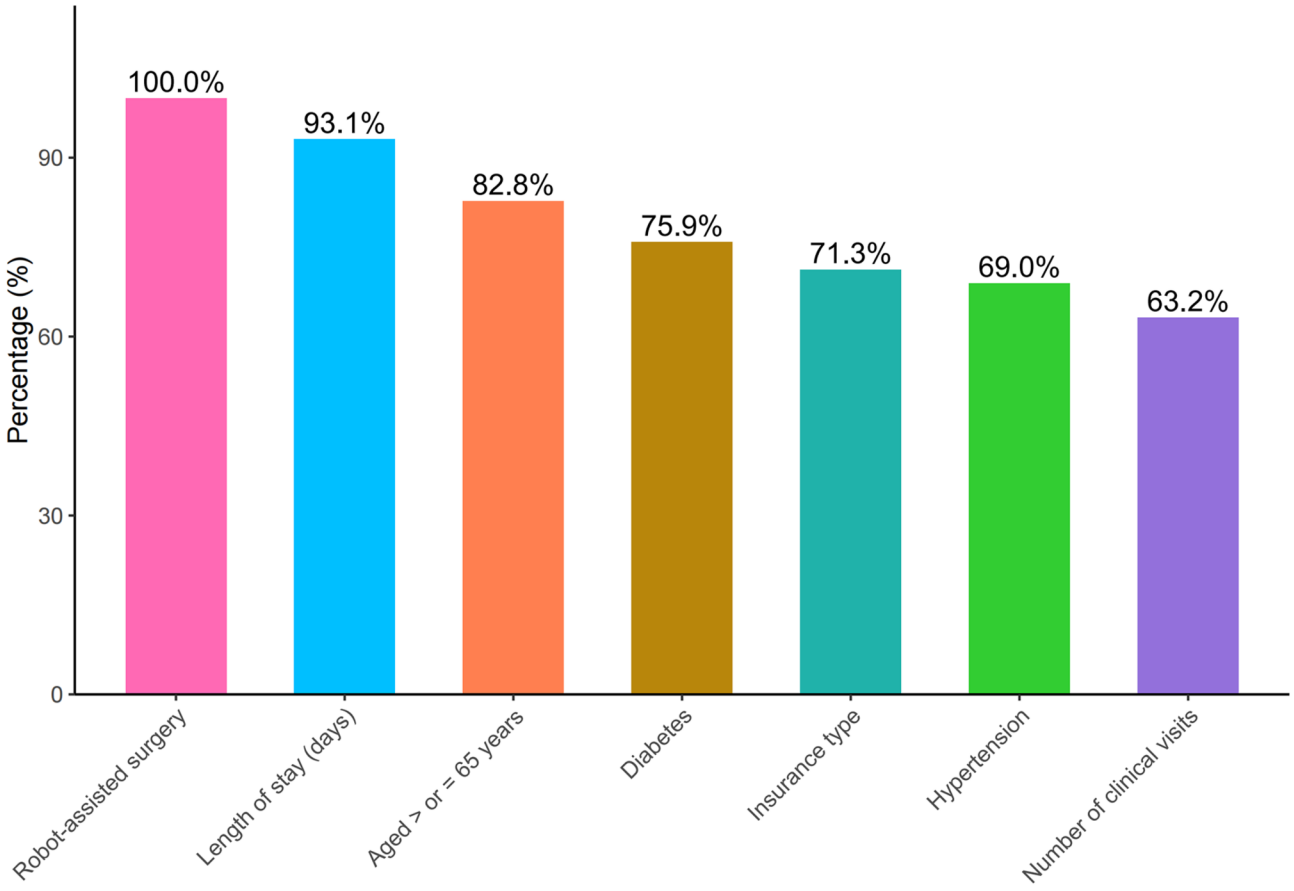

Fig. 2 Frequency analysis of factors potentially contributing to elevated hospitalization costs in MA13 patients

Discussion

The rising global incidence of male reproductive organ malignancies underscores the need to evaluate the economic impact of surgical interventions, particularly robot-assisted techniques, within diagnosis-related group (DRG) frameworks [11]. While existing studies have explored hospital costs for oncologic surgeries, evidence specific to robotic procedures remains limited [10, 12]. DRG subgroup refinement is critical to address cost heterogeneity and ensure equitable reimbursement [13]. International experiences demonstrate that expanding DRG categories reduces intra-group variability and mitigates adverse incentives, though subgroup justification must balance cost homogeneity with clinical relevance [14]. Globally, approaches to costly technologies vary: the U.S. bundles robotic and conventional surgeries under MS-DRGs without add-ons. Globally, approaches to costly technologies vary: the U.S. bundles robotic and conventional surgeries under MS-DRGs without add-ons [15], Germany integrates robotics into G-DRG tariffs [16], and the U.K. assigns specific HRG codes contingent on outcome evidence [17]. These models highlight the necessity of cost-effectiveness data to justify supplementary payments. For China, temporary innovation funds or outcome-linked reimbursements may align DRG reform with cost-containment goals while fostering technological advancement. Future studies must integrate clinical outcomes (e.g., complication rates, hospital stays) to determine whether robotic surgery's higher upfront costs are offset by long-term savings.

Multilinear regression of clinical factors influencing hospitalization costs identified robot-assisted surgery and age as independent cost drivers (Table 4). Robot-assisted procedures increased costs by ¥37,424 compared to non-robotic approaches, with subgroup analyses demonstrating reduced cost variability when stratifying by robotic use (Table 5; Fig. 4). This disparity likely reflects prostatectomy-specific resource demands (95.8% of cases), including advanced imaging and prolonged operative time. Rare malignancies (e.g., penile cancer, $n = 9$) lacked sufficient data for analysis, underscoring the need for expanded datasets to validate universal cost drivers. While robot-assisted surgery offers clinical advantages, such as reduced complications and improved outcomes [18], current CHS-DRG reimbursement fails to address its financial burden, disincentivizing adoption. Globally, compensation mechanisms for robotic techniques include supplementary payments or adjusted grouping

Table 4 Multilinear regression analysis of total hospitalization costs

	β	cost increase (%)	t value	*P* value	VIF
Age (years)					1.032
<65	Reference				
≥65	1217.46	2.56	5.471	< 0.001	
LOS (days)					1.057
≤7	Reference				
>7	7008.74	14.73	34.626	< 0.001	
Number of clinical visits					1.020
1	Reference				
2	996.23	2.09	4.930	< 0.001	
≥3	284.08	0.60	0.844	0.398	
Insurance type					1.089
full self-pay	Reference				
URMI	1428.07	3.00	4.405	< 0.001	
UEMI	1118.97	2.35	3.486	0.001	
Robot-assisted surgery					1.065
no	Reference				
yes	37420.83	78.64	190.241	< 0.001	
Hypertension					1.034
no	Reference				
yes	398.83	0.84	2.051	0.040	
Diabetes					1.035
no	Reference				
yes	88.04	0.18	0.335	0.738	
TNM					1.010
I	Reference				
II	99.21	0.21	0.396	0.692	
III	1137.36	2.39	2.678	0.007	
IV	2867.91	6.03	3.245	0.001	

***LOS**: length of stay;**URMI**: urban resident medical insurance;**UEMI**: urban employee medical insurance;**TNM**: tumour-node-metastasis;**VIF**: variance inflation factor.**cost increase(%)**:β/reference group mean cost×100*

[19], suggesting China could explore similar strategies. However, selection bias remains a concern: patients selected for robotics were older and more comorbid (Table 6), potentially conflating cost differences with unmeasured complexity. Propensity-score matching in future studies could isolate robotic-specific cost impacts. To mitigate risks of overuse or gaming, outcome-linked reimbursement (e.g., penalties for unjustified robotic utilization) and post-hoc audits should accompany supplementary payments. This approach balances financial equity with technological advancement while safeguarding against system exploitation.

The prevalence of prostate cancer is significantly associated with age, exhibiting a significant increase in incidence observed as men age. In China, the 5-year survival rate for patients with prostate cancer in major cities has approached that of developed countries in Europe and the United States, where age remains an important prognostic factor [20, 21]. The overall health status of elderly patients is crucial in determining the appropriateness of surgical interventions. Older patients frequently exhibit physiological changes, including impaired cardiopulmonary function, weakened immune responses, and a higher prevalence of comorbidities, all of which enhance surgical risk [22]. Conventional prostate cancer surgery methods are associated with significant disadvantages, including extensive trauma, prolonged postoperative recovery periods, and substantial blood loss. Although these factors may be less alarming for younger patients, they pose significant risks for elderly patients [23]. Table 6 illustrates that elderly patients with hypertension and diabetes prefer robot-assisted surgery, which significantly reduces postoperative complications. Elderly patients experience higher hospitalization costs for conventional prostate cancer procedures than younger patients (Table 4). This indicates that hospitalization costs of MA13a-NR are lower than those of MA13b-NR. The difference in hospitalization costs between younger and older patients with prostate cancer undergoing robot-assisted surgery is minimal. Therefore, robot-assisted surgery, characterized by higher precision and flexibility, reduced intraoperative blood loss, and lower postoperative complication rates, is increasingly emerging as the preferred option for elderly patients with prostate cancer. However, to mitigate complexity, we recommend a hybrid approach: retaining the MA13 group while introducing supplementary payments for robot-assisted surgery. This balances precision and practicality, ensuring equitable reimbursement without proliferating subgroups.

While our study identified age and robotics as primary cost drivers, the inclusion of TNM staging (Table 4) revealed previously unmeasured oncologic heterogeneity. Advanced tumor stages (III/IV) increased hospitalization costs by 1.1–2.9 thousand CNY, likely attributable to prolonged operative time, higher complication risks, or adjuvant intraoperative therapies. This aligns with prior studies demonstrating that locally advanced malignancies require more complex resections and multidisciplinary care [24]. However, the limited cost impact of staging (accounting for < 6% of total variation) suggests systemic factors like technology adoption dominate financial burdens in this cohort. Future DRG refinements should consider integrating TNM staging alongside age and robotics. While our current subgrouping (Table 5) improved homogeneity (CV 0.12–0.35 vs. original 0.41), residual variation may stem from unmeasured stage-specific resource use.

To address the disincentives for robotic surgery adoption under China's CHS-DRG framework, a multiphased reform strategy could integrate international best

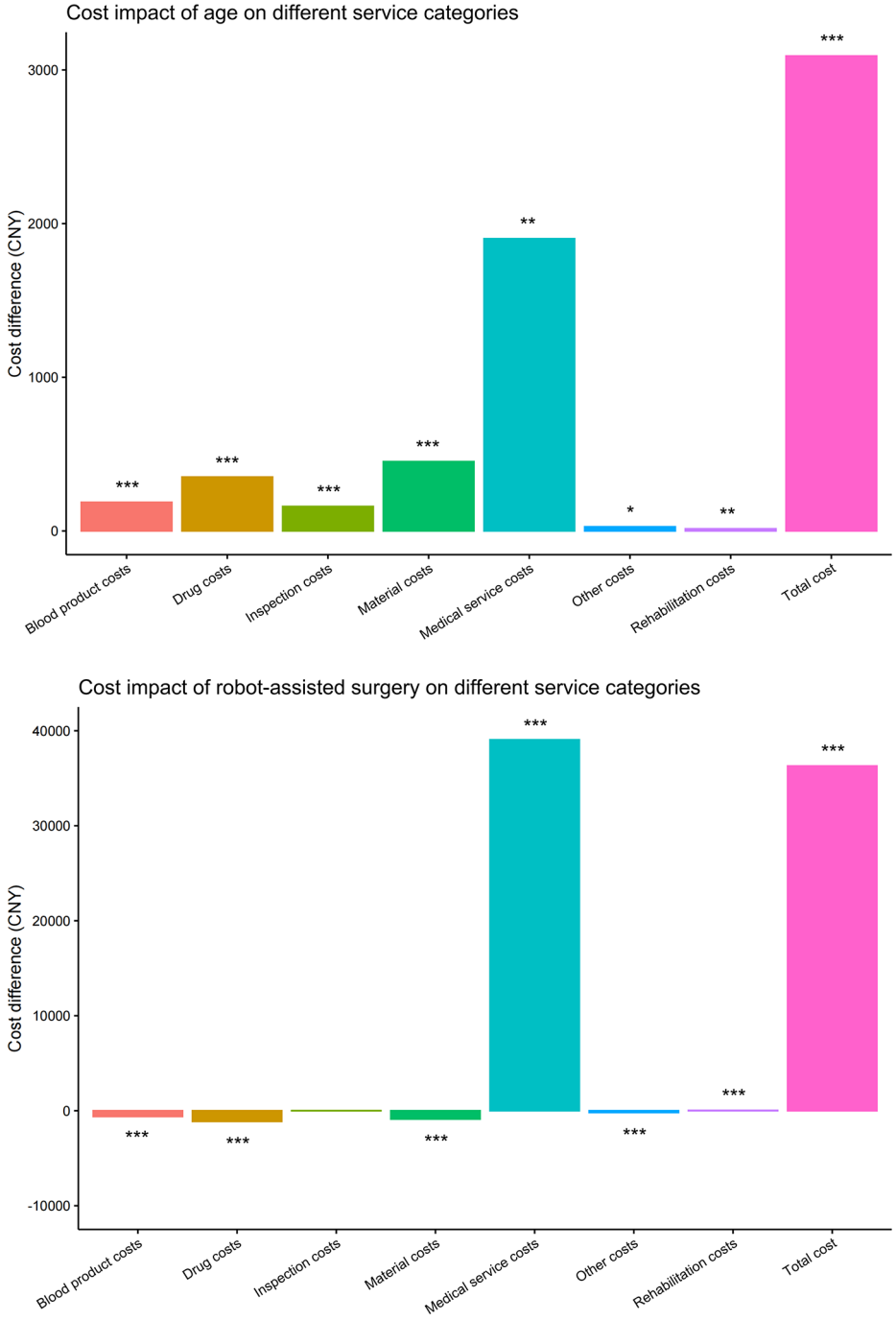

Fig. 3 Differential cost impact of age and robot-assisted surgery across service categories in MA13 patients

practices with domestic pilot innovations. First, pilot subgrouping of MA13 into robotic and non-robotic cohorts aligns with the 2.0 DRG grouping scheme's emphasis on refined clinical categorization and real-world data monitoring. This approach mirrors the "temporary innovation funds" mechanism proposed in recent reforms, allowing localized evaluation of cost homogeneity and behavioral impacts within 30 national monitoring cities. Second, outcome-linked payments should be introduced, contingent on demonstrated clinical benefits such as reduced complication rates or shorter hospital stays. This reflects Germany's model where robotic procedures are integrated into G-DRG tariffs without surcharges but supported by state-funded infrastructure investments. Such conditional reimbursements align with China's "exclusion mechanism" for new technologies, permitting temporary project-based payments during data collection phases. Third, dynamic DRG weighting through

Table 5 Costs information and t-test result of subgroups of MA13

Subgroup	Number of cases	Payment standard	Average costs	Min. costs	Max. costs	SD	CV	t value	*P* value
MA13a-R	674	/	64471.12	19296.08	109593.38	7754.83	0.12	0.657	0.551
MA13b-R	2144	/	64697.94	18367.34	104655.78	7834.80	0.12		
MA13a-NR	668	/	25900.57	7432.71	86572.77	9005.92	0.35	9.813	< 0.001
MA13b-NR	1832	/	29246.07	4888.36	88941.62	6937.47	0.24		
MA13	5318	55162.62	47582.98	4888.36	109593.38	19705.07	0.41	/	/

SD: *standard deviation;****CV***: *coefficient of variation. All costs are presented in Chinese Yuan (CNY). The name of DRG group:* ***MA13****, Surgery for malignant tumors of male reproductive organs, accompanied by general complications and comorbidities.****MA13a-R****: Age < 65 with robot-assisted surgery.****MA13b-R****: Age ≥ 65 with robot-assisted surgery.****MA13a-NR****: Age < 65 without robot-assisted surgery.****MA13b-NR****: Age ≥ 65 without robot-assisted surgery*

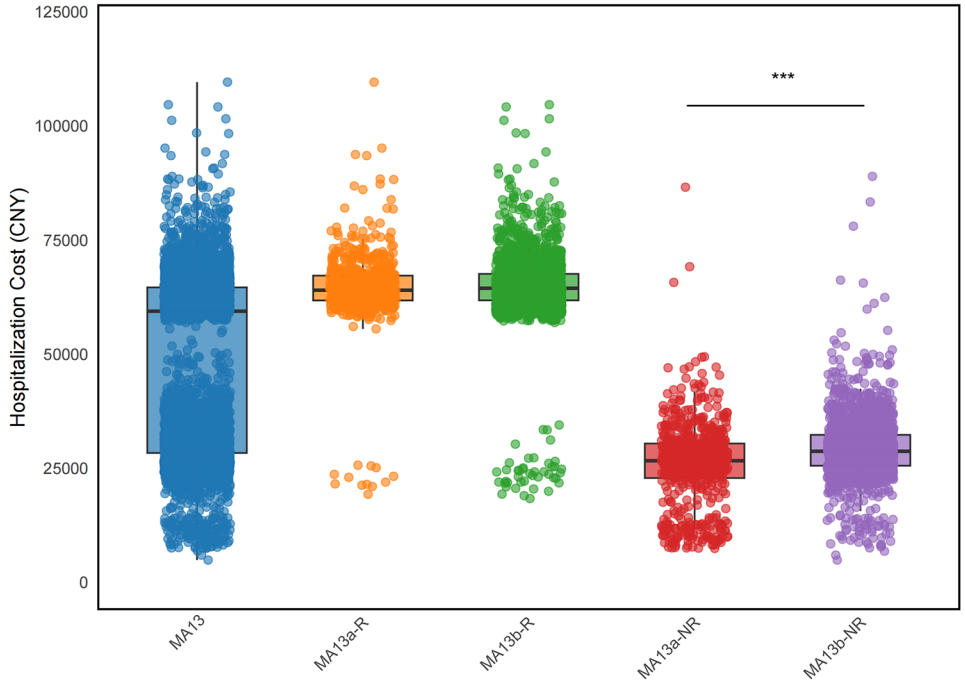

Fig. 4 Comparative cost distribution across MA13 patient subgroups: combined stratification by robot-assisted surgery (yes or no) and age (< 65 years or ≥ 65 years). MA13a-R: Age < 65 with robot-assisted surgery. MA13b-R: Age ≥ 65 with robot-assisted surgery. MA13a-NR: Age < 65 without robot-assisted surgery. MA13b-NR: Age ≥ 65 without robot-assisted surgery

Table 6 Results of multivariate logistic regression model

Variables	β	SE	OR (95%CI)	*P* value
Age (≥ 65 years)	0.129	0.064	**1.137 (1.004–1.288)**	**0.043**
Hypertension (yes)	0.183	0.056	**1.201 (1.076–1.341)**	**0.001**
Diabetes (yes)	0.330	0.077	**1.391 (1.197–1.618)**	**< 0.001**
TNM(II)	-0.161	0.073	**0.851 (0.738–0.982)**	**0.027**
TNM(III)	-0.113	0.123	0.893 (0.702–1.137)	0.357
TNM(IV)	-0.317	0.256	0.728 (0.438–1.204)	0.216

SE: *standard error;****OR***: *odds ratio;* ***CI***: *confidence interval*

machine learning could optimize fiscal sustainability, as seen in the 2.0 scheme's commitment to annual/ biennial grouping updates based on evolving clinical evidence and cost patterns. By integrating these measures, China's DRG system can balance technological advancement with cost containment, echoing global trends where payment reforms prioritize both clinical value and financial accountability.

This study has several limitations that warrant consideration. First, findings from a high-volume tertiary hospital may lack generalizability to smaller or rural settings, particularly given the high robotic surgery adoption rate (53%). Multi-center validation across diverse healthcare contexts is essential to confirm subgrouping applicability. Second, the MA13 group's homogeneity—predominantly prostate cancer cases (91.2%) undergoing radical prostatectomy—limits generalizability to broader populations with diverse tumor types (e.g., testicular or penile cancers). Future studies should validate subgrouping efficacy in multi-disease cohorts. Third, data constraints excluded critical clinical variables (e.g., surgical duration, survival, complication rates), necessitating integration of such metrics in subsequent analyses. Fourth, pooled data from 2021 to 2024 did not account for time-dependent factors (e.g., learning curves, policy shifts), potentially masking cost dynamics. Additionally, coding accuracy

and outlier handling were not rigorously addressed, affecting SD/CV reliability. Fifth, the absence of clinical outcomes (e.g., complications, survival) limits cost-effectiveness justifications for robotic surgery reimbursement. Finally, systemic financial implications (e.g., insurer budgets, provider incentives) and risks of unintended consequences (e.g., robotic overuse) remain unexplored. These limitations highlight the need for outcome-integrated, multi-institutional studies to optimize DRG reforms.

Conclusion

The MA13 group exhibited a comparatively higher CV in hospitalization costs, indicating less consistency within the group. Robot-assisted surgery and age were identified as two independent factors significantly affecting hospitalization costs, with robotic procedures increasing total costs by an average of 41,873 CNY. To balance technological accessibility and reimbursement fairness, we recommend hybrid solutions such as supplementary payments to the existing MA13 standard rather than creating entirely new DRG categories. This approach preserves database simplicity while addressing cost heterogeneity. Future prospective studies and national-scale validations are critical to evaluate the long-term economic and clinical impacts of robotic surgery integration. Pilot programs in 30 national monitoring cities, supported by temporary innovation funds and machine learning-driven DRG weight optimization, could refine implementation strategies. Our framework provides a template for DRG revisions in other high-cost specialties (e.g., cardiology, neurosurgery), emphasizing the need to maintain equilibrium between cost consistency, technological advancement, and administrative feasibility.

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Author contributions
ZZ and YL (Yunhe Li) designed the research. ZZ, XY, RD and WJ collected and organized data. ZZ, and YL (Ying Li) analyzed the data. ZZ and YL (Yunhe Li) drafted the manuscript. YL (Yunhe Li) contributed to the critical revision of the manuscript. All authors contributed to the manuscript and approved the submitted version.

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Data availability
The datasets used for this study are available on request to the corresponding author.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. The Clinical Research Ethics Committee of the First Affiliated Hospital, College of Medicine, Zhejiang University approved the study (grant nos. IIT20241621A). Written informed consent for participation was not required for this study due to its retrospective design, and the study was undertaken in accordance with national legislation and institutional requirements.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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