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Keywords: colorectal cancer, endoscopic mucosal dissection, endoscopic mucosal resection, health economics

Posted Date: August 11th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10234904/v1>

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Additional Declarations: No competing interests reported.

Analysis of Factors Affecting Hospitalization Costs in Patients with Colorectal Precancerous Lesions and Early-Stage Colorectal Cancer Treated with Endoscopic Submucosal Dissection and Endoscopic Mucosal Resection

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Funding Project

National Major Science and Technology Special Project for the Prevention and Treatment of Cancer, Cardiovascular and Cerebrovascular Diseases, Respiratory Diseases, and Metabolic Diseases; **Project Title:** Research on Mechanisms and Models for the Promotion of Technologies for the Prevention and Treatment of Chronic Diseases; **Project Number:** 2023ZD0509801

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Conflict of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

The data generated in this study are not publicly available because the information contained could compromise patient privacy or violate the terms of participant consent. However, the data are available upon reasonable request to the corresponding author.

Abstract: Purpose To compare differences in inpatient costs between endoscopic submucosal dissection (ESD) and endoscopic mucosal resection (EMR) for the treatment of patients with colorectal neoplastic lesions (including precancerous lesions and early-stage cancer), analyze the associated influencing factors, and conduct short-term and long-term cost-effectiveness evaluations, so as to provide a basis for clinical procedure selection and optimization of healthcare resource allocation. **Methods** Clinical data were retrospectively collected from 144 patients treated with ESD and 95 patients treated with EMR. Univariate analyses were performed using the Mann-Whitney U test and the Kruskal-Wallis H test. Multivariate linear regression and quantile regression models were further used to explore the influencing factors across different levels of cost distribution. **Results** Both univariate and multivariate linear regression analyses indicated that occupation, lesion site, maximum tumor diameter, and length of hospital stay were independent factors influencing hospitalization costs for ESD procedures ($P < 0.05$); pathological findings, maximum tumor diameter, number of adenomas, and length of hospital stay were independent factors influencing hospitalization costs for EMR procedures ($P < 0.05$). Quantile regression results showed that in the ESD group, hospitalization costs for patients who were specialized technical personnel decreased significantly at the 50th quantile ($P = 0.044$), while unemployed patients exhibited a negative effect on costs at the 25th and 90th quantiles ($P = 0.05$). Compared to lesions located in the right half of the colon, costs for lesions in the left half of the colon were significantly lower at the 25th percentile, and costs for rectal lesions were significantly lower at the 50th percentile ($P < 0.05$). A maximum tumor diameter ≥ 2 cm significantly increased hospitalization costs at the 50th percentile ($P = 0.007$); a hospital stay of ≥ 11 days had a positive effect on costs at the 10th, 25th, 50th, and 75th percentiles ($P < 0.05$). Quantile regression analysis in the EMR group showed that a pathological diagnosis of early-stage cancer significantly increased hospitalization costs at all cost percentiles ($P < 0.01$); a maximum tumor diameter ≥ 2 cm significantly increased costs at the 10th to 75th percentiles ($P < 0.05$); 3 or more adenomas significantly increased costs only at the 25th percentile ($P = 0.032$); a length of hospital stay ≥ 11 days had a significant positive effect on hospitalization costs at the

25th, 50th, and 75th percentiles ($P < 0.05$). **Conclusion** Hospitalization costs for ESD and EMR treatments of colorectal lesions are influenced by multiple factors, and these factors exhibit heterogeneity across different cost quantiles. Length of hospital stay is the most robust positive cost driver for both surgical procedures, with a particularly pronounced effect in the mid-cost range. This suggests that in clinical practice, developing individualized treatment plans based on tumor size, lesion location, and patient occupational background, and shortening hospital stays through Enhanced Recovery After Surgery (ERAS) strategies, are key to achieving optimal allocation of healthcare resources.

Keywords: colorectal cancer; endoscopic mucosal dissection; endoscopic mucosal resection; health economics

Data from the National Cancer Center shows that the incidence and mortality rates of malignant tumors in China are both rising annually^[1]. The average annual medical expenditure related to these diseases has exceeded 220 billion yuan, and the heavy disease burden has severely impacted China's socioeconomic development^[2,3]. According to projections from the Global Burden of Disease study, China is expected to suffer the most severe cancer-related economic losses globally between 2020 and 2050.

Colorectal cancer (CRC) imposes a particularly heavy burden among all types of malignant tumors. According to the 2022 Global Cancer Statistics Report, CRC ranks third globally in incidence and second in mortality^[4]. China is a high-incidence region for CRC, accounting for 26.8% of global cases and 26.5% of global CRC-related deaths, respectively^[5]. In China, CRC ranks second in incidence and fourth in mortality among all cancer types^[6]. Therefore, the prevention and treatment of CRC and its precancerous lesions have become an urgent public health challenge in China^[7].

Technological advancements in endoscopic treatment have created an opportunity to reverse this trend. Thanks to its advantages of minimal invasiveness, rapid recovery, and few complications, the 5-year survival rate for early-stage CRC and precancerous lesions can exceed 90% after standardized endoscopic treatment^[8,9]. Authoritative guidelines both domestically and internationally consistently recommend endoscopic treatment as the first-line option for lesions evaluated as suitable for endoscopic resection (either en bloc or piecemeal)^[10,11].

Currently, endoscopic mucosal resection (EMR) and endoscopic submucosal dissection (ESD) are the two most widely used minimally invasive procedures in clinical practice^[12]. With the continuous development of minimally invasive technologies and instruments, as well as the accumulation of clinical surgical experience, the safety and efficacy of minimally invasive treatment for CRC have improved significantly. This has made it an important curative option for resectable advanced CRC^[13,14].

However, different treatment regimens consume significantly different amounts of medical resources. While ensuring therapeutic efficacy, optimizing resource allocation and reducing the financial burden on patients have become key priorities in clinical

decision-making. Therefore, conducting a health economic evaluation of ESD and EMR to identify the key factors influencing hospitalization costs is of great significance for formulating cost-effective treatment strategies and reducing the overall disease burden of colorectal cancer. By comparing the cost structures of these two surgical procedures, this study aims to provide a scientific and rational basis for medical decision-making for clinicians and patients.

1 Materials and Methods

1.1 Sample Size Estimation

In accordance with statistical requirements, the sample size was calculated using a formula-based method (see Appendix A Formula 1). The results indicated that a sample size of 88 patients was required for each group; accordingly, it was determined that the ESD group and the EMR group in this study would each include no fewer than 88 patients.

1.2 Research Subjects

This retrospective study collected case data from patients who underwent endoscopic treatment at the General Hospital of the Chinese People's Liberation Army between January 2018 and December 2019. Inclusion criteria were: patients undergoing their first colonoscopy with pathological biopsy, with a presumptive diagnosis of colorectal precancerous lesions and/or early-stage cancer, and who underwent EMR or ESD surgery, respectively. Patient personal information was anonymized throughout the study, which strictly adhered to medical research ethics guidelines and was approved by the hospital's ethics committee.

1.3 Data Collection and Definitions

This study employed a retrospective cohort design to systematically collect patients' baseline data, perioperative information, and 5-year postoperative follow-up data. Baseline data were extracted from the Hospital Information System (HIS) and the pathology database, covering demographic characteristics (age, sex, BMI), lesion characteristics (location, histological type, maximum tumor diameter), and pre-treatment status (medical history and history of interventions). Surgical data focused on recording the surgical approach and whether en bloc resection was performed. Follow-up data were collected up to 5 years postoperatively, primarily documenting long-term postoperative complications (abnormal bowel movements, constipation, diarrhea, bloating, nausea and vomiting, dyspepsia, etc.) and adenoma recurrence.

Definition of outcome measures:

Primary outcome: 5-year recurrence rate of colorectal adenomas after surgery.

Secondary outcomes: en bloc resection rate, length of hospital stay, and incidence of

long-term postoperative complications.

Related definitions:

- ① En bloc resection: Refers to the complete removal of the lesion under endoscopic guidance, resulting in a single specimen^[15].
- ② Adenoma recurrence: Refers to the detection of an adenoma (including new adenomas and previously undetected adenomas) at the original surgical site or in another segment of the intestine during a follow-up colonoscopy performed ≥ 6 months after adenoma resection^[16-18].

1.4 Inclusion and Exclusion Criteria

1.4.1 Inclusion Criteria

Patients must meet all of the following criteria: ①First hospitalization for colorectal lesions, confirmed by colonoscopy and pathology as precancerous lesions or early-stage colorectal cancer; ②Precancerous lesions include adenomas, adenomatosis, and dysplasia associated with inflammatory bowel disease; ③Early-stage cancer is limited to stage M (intramucosal carcinoma) or stage SM (submucosal carcinoma) in the TNM classification; ④No history of malignant tumors in the gastrointestinal tract or other systems; ⑤At least one follow-up total colonoscopy performed ≥ 6 months post-surgery; ⑥Complete clinical and follow-up data; ⑦Willingness to cooperate with long-term follow-up evaluations.

1.4.2 Exclusion Criteria

Participants meeting any of the following conditions will be excluded: having concurrent malignant tumors in other systems; exhibiting poor compliance that prevents cooperation with treatment or follow-up; having concurrent severe cardiac, pulmonary, hepatic, or renal insufficiency; having concurrent hematological disorders or coagulation disorders; or having missing key clinical or follow-up data.

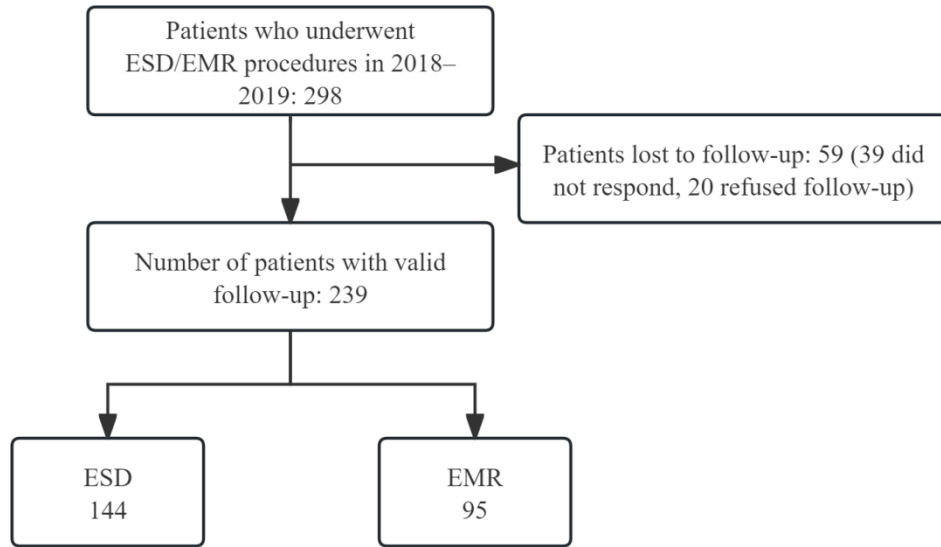


Fig. 1

Flowchart of the Study Subject Enrollment Process

1.5 Quality Control

To ensure the accuracy and completeness of research data, the following quality control measures are implemented:

Data Entry Management: Data entry is performed by trained professional medical records staff to ensure the authenticity and traceability of source data.

Subject Selection Control: Study subjects are strictly screened according to predefined inclusion and exclusion criteria to minimize selection bias.

Data Cleaning and Verification: The database undergoes logical verification and outlier detection, and obvious errors are corrected promptly.

Cross-database Comparison: Consistency checks are performed on duplicate variables from different systems to ensure data uniformity.

Handling of Missing Data: Attempts are made to supplement missing data from other databases; data that cannot be supplemented is treated as missing.

Handling of Inconsistent Data: For conflicting variables, the decision to use the most recent value or treat the data as missing is made based on clinical significance and the study objectives.

1.6 Scope of the Study

This study aims to analyze the factors influencing hospital costs for patients with

colorectal adenomas and early-stage colorectal cancer treated with ESD and EMR. The independent variables included in the analysis are: sociodemographic characteristics (gender, age, BMI, occupation); clinical characteristics (comorbidities, lesion location, pathological findings, histological subtype, maximum tumor diameter, number of adenomas); and healthcare resource utilization (length of hospital stay). This study focuses on identifying key factors that significantly influence the aforementioned hospitalization costs, as well as on comparing and interpreting these factors.

1.7 Statistical Analysis Methods

(1) One-way and Multi-way Analysis

Since hospital costs follow a non-normal distribution, quantitative data are presented as the median (interquartile range) [M (P25, P75)]. The Mann–Whitney U test was used to compare differences in the distribution of hospitalization costs between patients of different genders and between patients receiving different surgical procedures; the Kruskal–Wallis H test was used for comparisons among multiple categorical groups, and pairwise comparisons between groups were adjusted using the Bonferroni method. Variables with $P < 0.1$ in the univariate analysis were included in a multiple linear regression model to examine the independent effects of each factor on hospitalization costs.

(2) Quantile Regression

The quantile regression model (QRM) can identify how covariates influence the dependent variable across different quantiles as covariates change, and it is particularly well-suited for analyzing data with heteroscedasticity. This model is not restricted to predicting and examining the effects of relevant variables across numerical ranges and positions; it also visualizes the estimated coefficients of quantile regression, delivers in-depth interpretations of regression results at different quantiles, and systematically explores the effects of covariates on the dependent variable in terms of position, scale, and shape. In this way, it provides a more flexible analytical perspective for correlation studies in the social sciences^[19]. QRM adopts the Least Absolute Deviation (LAD) method, rather than the traditional Ordinary Least Squares (OLS) method.

The basic form of the quantile regression model is presented in Appendix A Formula

2^[20].

2 Results

2.1 Analysis of Factors Affecting Hospitalization Costs for Patients with Colorectal Adenomas and Early-Stage Cancer

2.1.1 One-Way Analysis

The results of the univariate analysis are presented in Table 3 in Appendix B.

(1) ESD Group

Occupation, maximum tumor diameter, and length of hospital stay were the primary factors influencing hospitalization costs. The per-capita hospitalization costs for patients in different occupational groups, from highest to lowest, were as follows: office workers (32,100 yuan), farmers (31,700 yuan), other workers (28,100 yuan), civil servants (28,000 yuan), manual laborers (26,500 yuan), professionals (26,500 yuan), and the unemployed (24,100 yuan). The cost differences between occupational groups were statistically significant ($H=14.030$, $P=0.029$). Pairwise comparisons revealed statistically significant cost differences between office workers and the unemployed or professionals, as well as between farmers and the unemployed or professionals ($P < 0.05$). Patients with a maximum tumor diameter of ≥ 2 cm had significantly higher hospitalization costs than those with < 2 cm (29,800 yuan vs. 25,300 yuan, $Z = -2.506$, $P = 0.012$), and patients with a hospital stay of ≥ 11 days also had significantly higher costs than those with a stay of < 11 days (31,200 yuan vs. 25,200 yuan, $Z = -3.349$, $P = 0.001$).

(2) EMR Group

Pathological findings, maximum tumor diameter, number of adenomas, and length of hospital stay were significantly associated with hospitalization costs ($P < 0.05$). Patients with early-stage cancer had higher hospitalization costs than those with precancerous lesions ($30,100 \pm 5,200$ yuan vs. $18,700 \pm 8,500$ yuan, $t = -3.923$, $P < 0.001$); patients with a maximum tumor diameter ≥ 2 cm had significantly higher costs than those with a maximum tumor diameter < 2 cm ($26,300 \pm 8,800$ yuan vs. $17,600 \pm 7,800$ yuan, $t = -4.556$, $P < 0.001$). Patients with ≥ 3 adenomas had significantly higher costs than those with < 3 adenomas ($22,400 \pm 9,500$ yuan vs. $18,400 \pm 8,300$ yuan, $t = -2.142$, $P = 0.035$).

Hospitalization costs were significantly higher for patients with a length of stay ≥ 11 days compared to those with a length of stay < 11 days ($27,800 \pm 9,000$ yuan vs. $17,400 \pm 7,400$ yuan; $Z = -5.462$, $P < 0.001$).

2.1.2 Multiple Linear Regression Analysis

Variables that showed statistically significant differences in the univariate analysis, as well as variables reported in the literature as potentially influencing hospitalization costs (BMI, occupation, tumor location, maximum tumor diameter, and length of hospital stay), were included in the multivariate analysis. All categorical variables were coded as dummy variables, and the results are presented in Table 4 of Appendix B.

(1) ESD Group

The regression model was statistically significant ($F = 4.022$, $P < 0.001$), with an adjusted R^2 of 0.251, indicating that the included variables explain 25.1% of the variance in hospitalization costs. The variance inflation factors (VIF) for all variables were < 10 , and the tolerance was > 0.1 , and the DW value was 1.653, indicating no multicollinearity and independent residuals.

The regression results showed that, compared with clerical staff, patients classified as professional and technical personnel ($\beta = -0.239$, $P = 0.037$) and the unemployed ($\beta = -0.311$, $P = 0.015$) had significantly lower hospitalization costs; compared with the right colon, costs were lower for lesions located in the rectum ($\beta = -0.241$, $P = 0.007$) and the left colon ($\beta = -0.182$, $P = 0.039$), with a more pronounced reduction in the rectum; a maximum tumor diameter of ≥ 2 cm ($\beta = 0.215$, $P < 0.05$) and a length of stay of ≥ 11 days ($\beta = 0.257$, $P < 0.05$) were independent risk factors for increased hospitalization costs.

(2) EMR Group

The regression model was statistically significant ($F = 13.926$, $P < 0.001$), with an adjusted R^2 of 0.663, VIF < 10 , and DW = 1.810, indicating a good model fit and absence of multicollinearity.

Regression results showed that, compared with precancerous lesions, early-stage cancer ($\beta = 0.229$, $P = 0.008$) significantly increased hospitalization costs; maximum tumor diameter ≥ 2 cm ($\beta = 0.300$), number of adenomas ≥ 3 ($\beta = 0.169$), and length of hospital

stay ≥ 11 days ($\beta = 0.381$) were all independently associated with increased hospitalization costs (all $P < 0.05$); BMI had no statistically significant effect on hospitalization costs ($P > 0.05$).

2.1.3 Quantile Regression Analysis

After selecting the statistically significant variables identified through multiple linear regression analysis, we constructed quantile regression models at the 10th, 25th, 50th, 75th, and 90th percentiles, which represent low, lower-middle, middle, upper-middle, and high cost levels, respectively. The results are shown in Table 1 and Figure 2.

(1) ESD Group:

Professional and technical staff had a significant negative effect on hospitalization costs at the 50th percentile ($\beta = -0.055$, $P = 0.044$), suggesting that among patients with moderate costs, this occupation is associated with lower hospitalization costs.

Unemployed patients had a significant impact on costs at the 25th percentile ($\beta = -0.098$, $P = 0.031$) and the 90th percentile ($\beta = -0.112$, $P = 0.027$), suggesting an association with both lower-to-middle and higher cost levels.

Lesions located in the left colon and rectum significantly reduced costs at the 25th ($\beta = -0.106$) and 50th ($\beta = -0.055$) percentiles, respectively ($P < 0.05$). A tumor with maximum diameter ≥ 2 cm had a significant positive effect on costs at the 50th percentile ($\beta = 0.057$, $P = 0.007$).

Length of hospital stay had a significant positive effect at the 10th, 25th, 50th, and 75th percentiles ($P < 0.05$), but the effect was not statistically significant at the 90th percentile ($P > 0.05$), suggesting that prolonged hospital stays primarily drive costs at the low-to-medium and medium-to-high levels, with limited impact on extremely high costs.

Tab. 1

Quantile Regression Estimates of the Logarithm of Inpatient Costs for ESD Surgery

Statistical variables	Statistical indicators	q10	q25	q50	q75	q90	OLS
Occupation (Control = Office Worker)							
National Civil Servant	Regression coefficient	0.017	-0.094	-0.044	-0.041	-0.172	-0.012
	Gradient standard error	0.078	0.065	0.055	0.064	0.088	0.021

Technical professional	<i>P</i>	0.829	0.147	0.418	0.525	0.053	0.558
	Regression coefficient	-0.161	-0.142	-0.110	-0.132	-0.222	-0.114
	Gradient standard error	0.106	0.101	0.054	0.100	0.231	0.054
Farmer	<i>P</i>	0.132	0.159	0.044	0.186	0.337	0.037
	Regression coefficient	0.019	-0.070	-0.008	-0.006	-0.107	-0.018
	Gradient standard error	0.083	0.083	0.055	0.075	0.136	0.054
Worker	<i>P</i>	0.818	0.396	0.885	0.939	0.434	0.741
	Regression coefficient	-0.019	-0.109	-0.089	-0.097	-0.151	-0.098
	Gradient standard error	0.096	0.066	0.055	0.078	0.131	0.052
Other personnel	<i>P</i>	0.844	0.098	0.112	0.220	0.249	0.061
	Regression coefficient	-0.001	-0.106	-0.051	-0.043	-0.129	-0.067
	Gradient standard error	0.071	0.064	0.048	0.067	0.085	0.046
Unemployed	<i>P</i>	0.988	0.099	0.285	0.522	0.134	0.146
	Regression coefficient	-0.160	-0.163	-0.094	-0.107	-0.224	-0.128
	Gradient standard error	0.098	0.083	0.051	0.072	0.113	0.052
<i>P</i>		0.106	0.050	0.067	0.138	0.050	0.015
Site of lesion (control = right colon)							
Left colon	Regression coefficient	-0.080	-0.106	-0.067	0.040	-0.087	-0.060
	Gradient standard error	0.064	0.044	0.049	0.044	0.116	0.029
	<i>P</i>	0.210	0.017	0.175	0.367	0.453	0.039
Rectum	Regression coefficient	-0.025	-0.053	-0.055	-0.014	-0.143	-0.066
	Gradient standard error	0.043	0.027	0.020	0.034	0.112	0.024
	<i>P</i>	0.565	0.054	0.006	0.681	0.206	0.007
Maximum tumor diameter (control = <2 cm)							
≥2cm	Regression coefficient	0.045	0.051	0.057	0.035	0.056	0.059
	Gradient standard error	0.057	0.031	0.021	0.024	0.063	0.021
	<i>P</i>	0.434	0.099	0.007	0.142	0.381	0.006
Length of hospital stay (control = <11 days)							

≥ 11 days	Regression coefficient	0.094	0.081	0.058	0.062	0.082	0.070
	Gradient standard error	0.025	0.020	0.014	0.031	0.045	0.021
	P	<0.001	<0.001	<0.001	0.047	0.069	0.001

Note: q10 = 18,400 yuan, q25 = 21,600 yuan, q50 = 26,400 yuan, q75 = 31,200 yuan, q90 = 37,200 yuan.

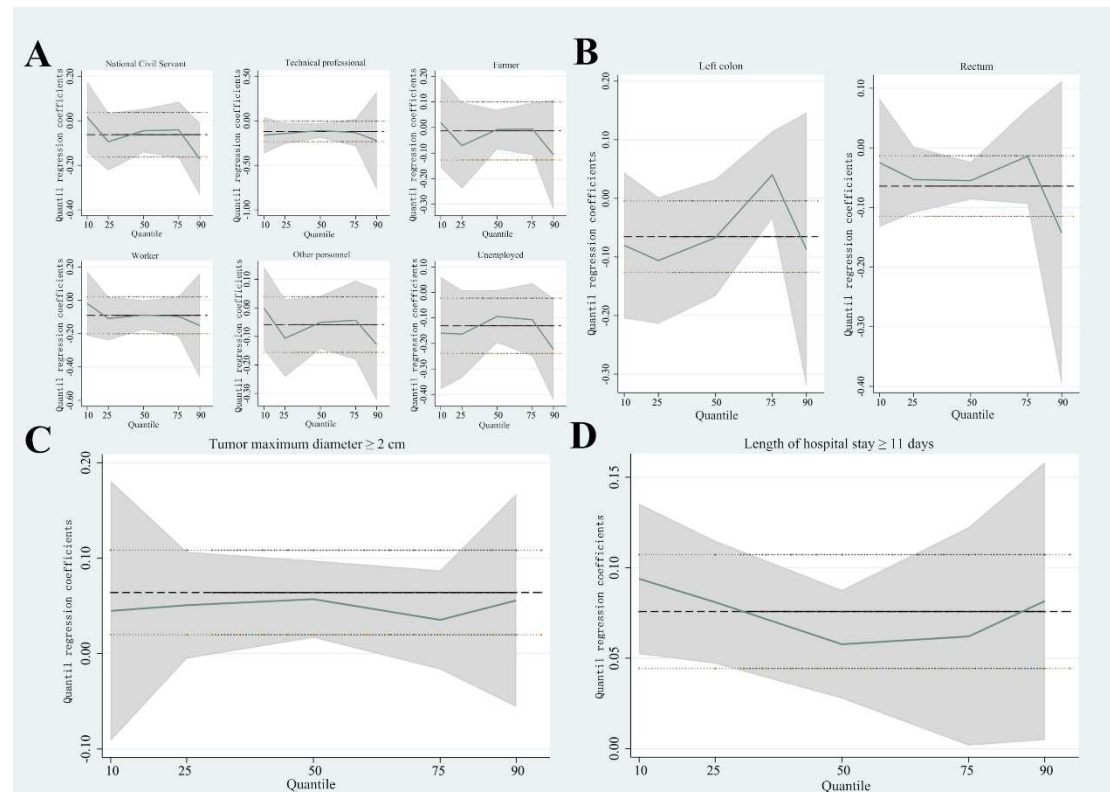


Fig. 2
 95% Confidence Interval Plot for ESD Quantile Regression Coefficients (Logarithm of Hospitalization Costs in Yuan)
 Note: (A) Occupational effect (B) Site-specific effect (C) Maximum tumor diameter effect (D) Length of hospital stay effect; q10 = 18,400 yuan, q25 = 21,600 yuan, q50 = 26,400 yuan, q75 = 31,200 yuan, q90 = 37,200 yuan.

(2) EMR Group

The results of the quantile regression analysis for hospitalization costs in the EMR group are presented in Table 2 and Figure 3.

Compared with patients with precancerous lesions, a pathological diagnosis of early-stage cancer had a positive impact on hospitalization costs across all quantiles (10%–90%), and these differences were all statistically significant ($P < 0.05$), suggesting that early-stage cancer is a consistent factor driving up hospitalization costs, regardless of

the overall cost level. A tumor maximum diameter ≥ 2 cm had a significant positive effect on hospitalization costs at the ≤ 75 th percentile (i.e., low, lower-middle, middle, and upper-middle cost levels) ($P = 0.007$); however, at the 90th percentile (high cost level), the effect was not statistically significant ($P > 0.05$). This indicates that tumor size is primarily closely associated with hospitalization costs at levels below the upper-middle range. A number of adenomas ≥ 3 had a significant positive effect on hospitalization costs only at the 25th percentile (low-to-medium cost level) ($P = 0.032$), suggesting that an increase in the number of adenomas primarily drives up medical expenditures for patients in the low-to-medium cost segments. Length of hospital stay had a significant positive effect on hospitalization costs at the 25th, 50th, and 75th percentiles ($P < 0.05$). Further quantification shows that for every one-unit increase in length of stay, the increase in hospitalization costs is most significant within the range of 11,800 to 26,000 yuan.

Tab. 2

Quantile Regression Estimates of Hospitalization Costs for EMR Surgery

Statistical variables	Statistical indicators	q10	q25	q50	q75	q90	OLS
Pathology Results (control = precancerous lesion)							
Early-stage cancer	Regression coefficient	1.180	1.424	1.312	0.942	0.674	0.694
	Gradient standard error	0.333	0.343	0.321	0.257	0.188	0.256
	<i>P</i>	0.001	<0.001	<0.001	<0.001	0.001	0.008
Maximum tumor diameter (control = <2 cm)							
≥ 2 cm	Regression coefficient	0.777	1.108	0.959	0.631	0.650	0.613
	Gradient standard error	0.364	0.238	0.212	0.307	0.674	0.170
	<i>P</i>	0.035	<0.001	<0.001	0.043	0.337	0.001
Number of adenomas (control = <3)							
≥ 3	Regression coefficient	0.233	0.479	0.443	0.359	0.187	0.314
	Gradient standard error	0.230	0.220	0.308	0.256	0.446	0.151
	<i>P</i>	0.313	0.032	0.154	0.164	0.676	0.040
Length of hospital stay (control = <11 days)							

≥ 11 days	Regression coefficient	0.094	0.081	0.058	0.062	0.082	0.070
	Gradient standard error	0.025	0.020	0.014	0.031	0.045	0.021
	<i>P</i>	<0.001	<0.001	<0.001	0.047	0.069	0.001

Note: Precancerous lesion group: Pathologically confirmed colorectal intraepithelial neoplasia, including low-grade intraepithelial neoplasia and high-grade intraepithelial neoplasia (including carcinoma in situ/mucosal carcinoma); Early-stage cancer group: Pathologically confirmed adenocarcinoma with invasion limited to the submucosal layer (pT1 stage), regardless of lymph node status; Q10 = 8,800 yuan, Q25 = 11,800 yuan, Q50 = 19,800 yuan, Q75 = 26,000 yuan, Q90 = 31,000 yuan.

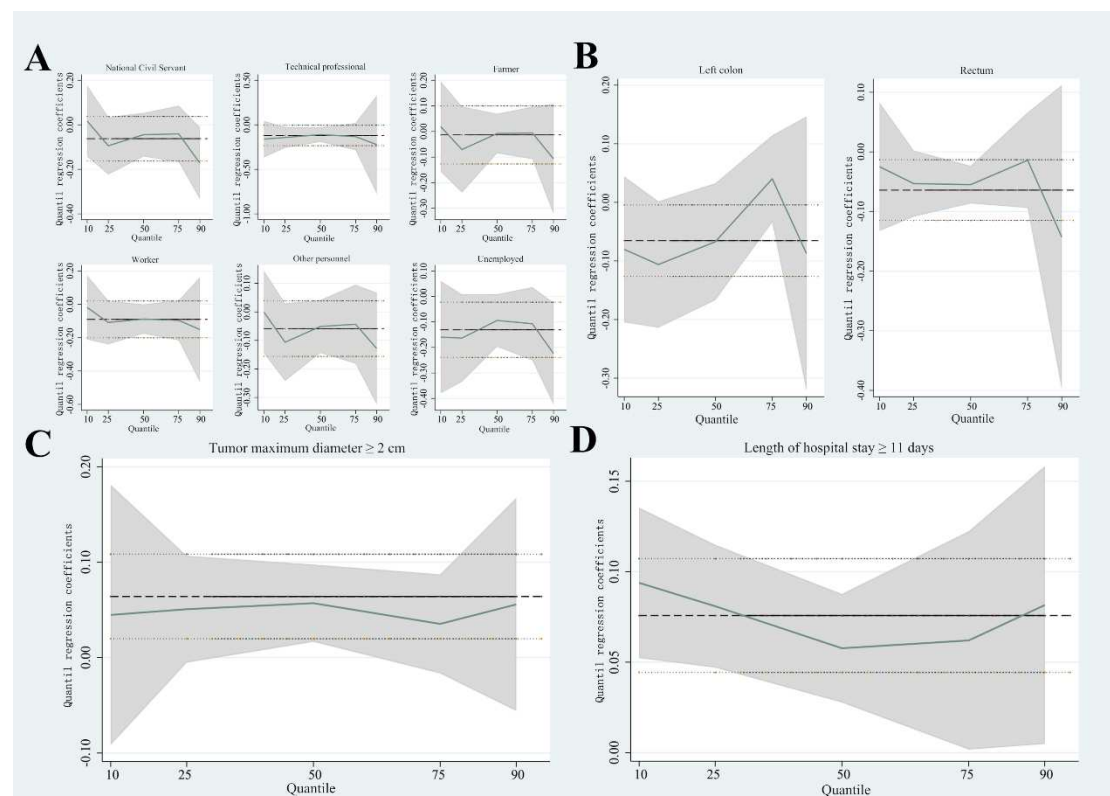


Fig. 3
95% Confidence Interval Plot for Quantile Regression Coefficients (Logarithm of Hospitalization Costs in Yuan)

Note: (A) Pathology result effect (B) Maximum tumor diameter effect (C) Number of adenomas effect (D) Length of hospital stay effect; q10 = 8,800 yuan, q25 = 11,800 yuan, q50 = 19,800 yuan, q75 = 26,000 yuan, q90 = 31,000 yuan.

3 Discussion

Health economic evaluations enhance the scientific rigor and transparency of healthcare decision-making, guide healthcare professionals in rationally allocating limited medical resources, and identify cost-effective treatment options that deliver significant clinical outcomes^[21]—ultimately alleviating the financial burden on patients. Grounded in economic theory and statistical analysis methods, this study systematically investigates

the key factors influencing hospitalization costs for patients with colorectal adenomas and early-stage cancer. It aims to generate empirical evidence to optimize resource allocation, support clinical decision-making, and inform the development of health policies.

3.1 Analysis of Factors Affecting Hospitalization Costs

This study performed univariate and multivariate analyses on patients treated with ESD and EMR, respectively. Univariate analysis showed that hospitalization costs in the ESD group were affected by occupation, maximum tumor diameter, and length of hospital stay ($P < 0.05$); in the EMR group, costs were influenced by pathological findings, maximum tumor diameter, number of adenomas, and length of hospital stay ($P < 0.05$).

After including the above variables and clinically relevant factors in a multiple linear regression model, the following results were obtained:

In the ESD group, occupation, lesion location, maximum tumor diameter, and length of hospital stay were independent predictors of hospitalization costs; in the EMR group, pathological findings, maximum tumor diameter, number of adenomas, and length of hospital stay were independent predictors of hospitalization costs.

Length of hospital stay was the strongest common influencing factor for both groups. Prolonged hospital stay leads to cumulative expenses for medication, nursing care, and bed fees, which significantly increases total hospitalization costs. This conclusion is consistent with previous research findings^[22-24]. Ge Xiaoyu et al^[25]. also pointed out that the impact of prolonged hospital stay on costs varies at different cost levels, indicating heterogeneity in cost structure. Maximum tumor diameter was another common influencing factor, and it had a positive effect on costs in both groups. As tumor diameter increases, surgical operations become more complex, leading to higher consumption of related consumables and treatment resources, which in turn results in higher costs.

In the ESD group, there were significant differences in hospitalization costs among patients of different occupations; the costs of skilled professionals and unemployed patients were lower than those of office workers. Patients with lesions located in the

rectum or left colon had significantly lower hospitalization costs than those with lesions in the right colon.

In the EMR group, patients with a pathological diagnosis of early cancer or three or more adenomas had significantly higher hospitalization costs, indicating that the nature and scope of lesions have a more significant role in promoting treatment costs.

The results of quantile regression further revealed the heterogeneous effects of the above influencing factors at different cost levels:

In the ESD group, specialized technical personnel had a significant negative effect at the 50th percentile, which may be related to health insurance type, healthcare-seeking behavior, and hospital management pathways; unemployed patients had negative effects at both the 25th and 90th percentiles, indicating that in the low-cost group, non-essential services may be reduced due to economic constraints, while in the high-cost group, patients are more dependent on health insurance coverage. A hospital stay of ≥ 11 days significantly increased costs in the low-to-mid-high cost range; left colon lesions had significantly lower costs at the 25th percentile, while rectal lesions had significantly lower costs at the 50th percentile, which may be caused by differences in surgical difficulty, medical consumables use, and postoperative management modes; a maximum tumor diameter of ≥ 2 cm significantly increased costs at the 50th percentile. In the EMR group, a maximum tumor diameter of ≥ 2 cm significantly increased costs in the low-to-medium cost range; a hospital stay of ≥ 11 days had a significant impact on the medium-cost range, but had only a limited effect on the extremely low-cost and extremely high-cost ranges; and having ≥ 3 adenomas significantly increased costs mainly at the 25th percentile, indicating that the financial burden is more prominent among low-to-middle income patient groups.

3.2 Limitations of This Study

This study has certain limitations. First, the lack of detailed cost data for each item collected during hospitalization prevents us from conducting an in-depth analysis of the cost structure and the specific mechanisms through which these components influence total medical expenses. Second, since this is a single-center retrospective study, the generalizability of our findings requires further validation through large-scale,

multicenter studies.

3.3 Summary

Occupation, tumor location, maximum tumor diameter, and length of hospital stay are the primary factors influencing ESD-related hospitalization costs; meanwhile, pathological findings, maximum tumor diameter, number of adenomas, and length of hospital stay are the primary factors influencing EMR-related hospitalization costs.

In clinical practice, healthcare providers should target these influential factors by optimizing hospital stay management within appropriate cost ranges and developing individualized treatment strategies. This approach can effectively control medical costs while guaranteeing the quality of care, and ultimately alleviate the financial burden on patients.

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Appendix A: Formulas Required for This Study

1. Formula for Sample Size Calculation

$$n = \frac{(Z_{\alpha}\sqrt{2\bar{p}\bar{q}} + Z_{\beta}\sqrt{p_0q_0 + p_1q_1})^2}{(p_1 - p_0)^2} \quad \text{Formula 1}$$

n represents the sample size per group (ESD group: EMR group = 1:1), Setting $\alpha=0.05$ (two-tailed), consulting the table yields $Z_{\alpha}=1.96$; With $\beta=0.10$, when the test power $(1-\beta)=0.9$, consulting the table yields $Z_{\beta}=1.28$; p_0 and p_1 are based on the study by Lin Wei et al^[24], representing the postoperative outcome rates for the ESD group and the EMR group, respectively. $\bar{P}$ is the average of the outcome rates for both groups, $q=1-p$, and the loss-to-follow-up rate is set at 20%.

2. Quantile Regression Model

$$Quant_{\theta}(Cost_i|X_i) = \gamma^{\theta} X_i \quad \text{Formula 2}$$

Let X_i be the covariate in the OLS regression model, and γ^{θ} be the regression coefficient associated with the quantile, representing the effect of X_i on different quantiles of Cost. Different values of θ result in different values of γ^{θ} , thereby capturing the varying effects of the covariate across different quantiles. This paper uses Stata MP 18.0 software to estimate the quantile regression coefficients γ^{θ} . It employs the Bootstrap densification algorithm to obtain confidence intervals for the sample by conducting 400 rounds of with-replacement bootstrap sampling, followed by the estimation of the model's regression coefficients.

Appendix B: Analysis of Factors Affecting Hospitalization Costs

1. Univariate Analysis of Hospitalization Costs for Patients with Precancerous Lesions and Early-Stage Colorectal Cancer Undergoing ESD and EMR Procedures

Tab. 3

Univariate Analysis of Hospitalization Costs for Patients with Precancerous Lesions and Early-Stage Colorectal Cancer Undergoing ESD and EMR Procedures

Type of Surgery	Statistical variables	Number of examples	Hospitalization costs (in 10,000 yuan)		<i>H/Z</i>	<i>P</i>
			Cost per person	Median ($P_{25} \sim P_{75}$)		
ESD	Gender				-0.612	0.541
	Female	60	2.69	2.64 (2.20~3.00)		
	Male	84	2.85	2.64 (2.12~3.19)		
	Age				-0.004	0.997
	<60	70	2.79	2.62 (2.12~3.16)		
	≥60	74	2.79	2.65 (2.19~3.02)		
	BMI (kg/m ²)				-0.278	0.781
	<24	82	2.82	2.69 (2.14~3.06)		
	≥24	62	2.74	2.50 (2.21~3.14)		
	Occupation				14.030	0.029
	Office worker ^b	9	3.21	3.01 (2.62~3.72)		
	National Civil	32	2.80	2.76 (2.16~3.18)		
	Servant					
	Technical professional ^a	13	2.65	2.34 (1.86~2.59)		
	Farmer ^b	14	3.17	3.04 (2.32~3.49)		
	Worker	16	2.65	2.43 (2.08~2.80)		
	Other personnel	42	2.81	2.73 (2.15~3.21)		
	Unemployed ^a	18	2.41	2.43 (1.86~2.75)		
	Complications				-0.640	0.522
	无	91	2.81	2.72(2.14~3.14)		
	有	53	2.75	2.48(2.18~3.02)		
	Pathology Results				-0.230	0.818
	Precancerous lesions	110	2.77	2.66(2.22~3.05)		
	Early-stage cancer	34	2.83	2.59 (2.08~3.44)		
	Site of lesion				5.274	0.072
	Right colon	46	3.12	2.82(2.40~3.15)		
	Left colon	32	2.67	2.41 (1.86~3.46)		
	Rectum	66	2.61	2.49(2.13~3.06)		

EMR	Pathological Tissue Classification				6.529	0.912
	Tubular adenoma	17	3.13	2.78 (2.13~3.61)		
	Villous adenoma	4	2.57	2.73 (1.66~3.32)		
	Villous tubular adenoma	59	2.76	2.67 (2.17~3.16)		
	Adenoma with in situ neoplasia	64	2.74	2.59 (2.14~3.04)		
	Maximum diameter of the tumor (cm)				-2.506	0.012
	<2	62	2.53	2.45(2.04~2.95)		
	≥2	82	2.98	2.78 (2.28~3.21)		
	Number of adenomas				-1.584	0.113
	<3	117	2.75	2.60 (2.13~3.04)		
	≥3	27	2.95	2.80 (2.40~3.47)		
	Length of hospital stay				-3.349	0.001
	<11	80	2.52	2.47 (1.99~2.96)		
	≥11	64	3.12	2.80 (2.34~3.40)		
	Gender				-0.271	0.787
	Female	31	1.94	0.77		
	Male	64	2.00	0.95		
	Age				-0.206	0.837
	<60	41	1.96	1.01		
	≥60	54	2.00	0.80		
	BMI (kg/m ²)				0.132	0.895
	<24	54	1.99	0.85		
	≥24	41	1.97	0.95		
	Occupation				0.824	0.554
	Office worker ^b	4	1.68	0.56		
	National Civil Servant	21	1.85	0.83		
	Technical professional ^a	2	2.29	0.93		
	Farmer ^b	6	2.27	0.92		
	Worker	14	2.23	1.24		
	Other personnel	41	1.87	0.81		
	Unemployed ^a	7	2.38	0.85		

Complications					-1.795	0.076
无	55	1.84	0.87			
有	40	2.17	0.90			
Pathology Results					-3.923	<0.001
Precancerous lesions	86	1.87	0.85			
Early-stage cancer	9	3.01	0.52			
Site of lesion					0.372	0.690
Right colon	40	2.05	0.92			
Left colon	36	1.88	0.86			
Rectum	19	2.02	0.91			
Pathological Tissue Classification					0.499	0.684
Tubular adenoma	36	2.04	0.98			
Villous adenoma	1	1.39	---			
Villous tubular adenoma	36	2.04	0.83			
Adenoma with in situ neoplasia	22	1.82	0.86			
Maximum diameter of the tumor (cm)					-4.556	<0.001
<2	71	1.76	0.78			
≥2	24	2.63	0.88			
Number of adenomas					-2.142	0.035
<3	62	1.84	0.83			
≥3	33	2.24	0.95			
Length of hospital stay					-5.463	<0.001
<11	73	1.74	0.74			
≥11	22	2.78	0.90			

Note: Amounts are expressed in ten thousand yuan, while statistical analysis is conducted in yuan.

Precancerous Lesions Group: Pathologically confirmed colorectal intraepithelial neoplasia, including low-grade intraepithelial neoplasia and high-grade intraepithelial neoplasia (including carcinoma in situ/mucosal carcinoma).

Early-Stage Cancer Group: Pathologically confirmed adenocarcinoma with invasion limited to the submucosal layer (pT1 stage), regardless of lymph node status.

2. Multifactorial Analysis of Hospitalization Costs for Patients with Precancerous Lesions and Early-Stage Colorectal Cancer Undergoing ESD and EMR Procedures

Tab. 4

Multivariate Analysis of Hospitalization Costs for Patients with Precancerous Lesions and Early-Stage Colorectal Cancer Undergoing ESD and EMR Procedures

Type of Surgery	Statistical variables	Unstandardized		Standardization coefficient	<i>t</i>	<i>P</i>	Collinearity	
		coefficient					Statistics	
		β	Standard error				Tolerance	VIF
ESD	Constant	4.409	0.058		76.017	<0.001		
	BMI (control = <24 kg/m ²)	-0.012	0.021	-0.045	-0.588	0.558	0.965	1.036
	Occupation (Control = Office Worker)							
	National Civil Servant	-0.012	0.021	-0.045	-0.588	0.558	0.965	1.036
	Technical professional ^a	-0.114	0.054	-0.239	-2.104	0.037	0.438	2.281
	Farmer ^b	-0.018	0.054	-0.039	-0.331	0.741	0.415	2.410
	Worker	-0.098	0.052	-0.226	-1.888	0.061	0.395	2.531
	Other personnel	-0.067	0.046	-0.224	-1.464	0.146	0.243	4.115
	Unemployed ^a	-0.128	0.052	-0.311	-2.474	0.015	0.359	2.782
	Site of lesion (control = Right colon)							
	Left colon	-0.060	0.029	-0.182	-2.089	0.039	0.746	1.341
	Rectum	-0.066	0.024	-0.241	-2.741	0.007	0.735	1.360
	Maximum tumor diameter (control = <2 cm)	0.059	0.021	0.215	2.793	0.006	0.955	1.047
	Length of hospital stay (control = <11 days)	0.070	0.021	0.257	3.346	0.001	0.958	1.043
EMR	Constant	0.656	0.227		2.896	0.005		
	BMI (control = <24 kg/m ²)	0.015	0.144	0.009	0.107	0.915	0.974	1.026
	Pathology Results (control = precancerous lesion)	0.694	0.256	0.229	2.711	0.008	0.881	1.135
	Maximum tumor diameter (control = <2 cm)	0.613	0.170	0.300	3.603	0.001	0.909	1.101
	Number of adenomas (group = <3)	0.314	0.151	0.169	2.082	0.040	0.961	1.041
	Length of hospital stay (control = <11 days)	0.801	0.175	0.381	4.590	<0.001	0.914	1.094

Note: Precancerous lesion group: Pathologically confirmed colorectal intraepithelial neoplasia, including low-grade intraepithelial neoplasia and high-grade intraepithelial neoplasia (including carcinoma in situ/mucosal carcinoma); Early-stage cancer group: Pathologically confirmed adenocarcinoma with invasion limited to the submucosal layer (pT1 stage), regardless of lymph node status.