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全球健康发展研究院
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智慧手术季刊

SMART Surgical Quarterly

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（An Internal Journal）

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SMART Surgical Quarterly

On May 19, 2023, PKU Institute for Globe Health and Development has launched the Survey of Medical Assessment for Robotic Technology (SMART), a longitudinal multi-center study in China. In order to ensure the SMART study progress to be updated timely and effectively among all the participants, The SMART Surgical Quarterly is launched accordingly as an internal journal. This quarterly journal will serve as a comprehensive platform to update the key information on the SMART progress as well as the progress for the parallel studies.

编辑部主任 Managing Editors

孙宇 SUN Yu：sunyu@nsd.pku.edu.cn　谢琛 Jane Xie：janexiechen@pku.edu.cn

Editorial Office: PKU Institute for Global Health and Development (www.ghd.pku.edu.cn)

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Robotic-Assisted versus Laparoscopic Low Anterior Resection for Mid-Low Rectal Cancer: A Health Technology Assessment

By Ziting Wu, Zerong Cai, Yin Shi, Yudan Yu, Yuhang Pan, Xuefeng Hu, Gordon G. Liu, and Beini Lyu*

Colorectal cancer ranks among the most prevalent digestive tract malignancies in China, with low anterior resection of the rectum being the predominant anal-preserving procedure. However, there remains inconsistency in research findings regarding the comparative effectiveness of robotic surgery versus laparoscopic surgery in rectal cancer treatment. This study aims to assess the cost-effectiveness of robot-assisted surgery compared to laparoscopic or open surgery in mid-low rectal cancer patients undergoing low anterior resection of the rectum from a societal perspective. It aims to establish a nationwide multicenter observational prospective cohort to evaluate the clinical efficacy, quality of life, and economic costs between robot-assisted versus laparoscopic and open surgery.

I. Background

Robot-assisted surgery (RAS) represents a significant advancement in clinical surgery, offering distinct advantages such as minimal invasiveness and expedited postoperative recovery compared to traditional open surgery. Colorectal cancer is highly prevalent in China, with low anterior resection of the rectum being the most widely performed anal-preserving procedure. Medical robot is increasingly utilized in such surgeries due to potential benefits including improved oncological outcomes, smaller incisions, and faster recovery. However, the higher costs associated with robotic surgery necessitate a comprehensive health economic evaluation to ascertain its value. Existing research primarily relies on modeling and small-scale clinical data, lacking long-term quality of

* Wu: Institute for Global Health and Development, Peking University; Cai: Department of Colorectal Surgery, the Sixth Affiliated Hospital, Guangdong Institute of Gastroenterology, and Guangdong Provincial Key Laboratory of Colorectal and Pelvic Floor Diseases, the Sixth Affiliated Hospital, Sun Yat-sen University; Shi: Department of pharmacy and National Clinical Research Center for Geriatric Disorders, Xiangya Hospital Central South University; Yu: Institute for Global Health and Development, Peking University; Pan: Institute for Global Health and Development, Peking University; Hu: Institute for Global Health and Development, Peking University; Liu: Institute for Global Health and Development, Peking University; Lyu: Institute for Global Health and Development, Peking University (email: blyu@pku.edu.cn).

life and cost-effectiveness analyses specific to the Chinese population. Thus, this study aims to fill this gap by conducting a nationwide multicenter prospective real-world observational cohort study to assess the cost-effectiveness of robotic surgery compared to laparoscopic and open surgery in mid-low rectal cancer patients.

II. Methods

This study is a nationwide multicenter cohort study and plans to include 12-16 centers with a follow-up period of 3 years. The study population comprises patients undergoing curative low anterior resection surgery for rectal cancer and includes robotic surgery, laparoscopic and open surgery. Based on 3-year disease-free survival (DFS) being the primary outcome, the study plans to enroll 1200 participants, including 540 participants each in the robotic surgery group and laparoscopic surgery group, and 120 participants in the open surgery group.

The inclusion criteria are patients who received low anterior resection surgery, with preoperative diagnosis of mid-low rectal adenocarcinoma (with the tumor edge distance from the anus ≤10cm on pelvic MRI), preoperative stage cT1-T3 N0-1, or post-neoadjuvant therapy ycT1-T3 Nx, no distant metastasis M0, American Society of Anesthesiologists (ASA) score ≤3, aged 18-75 years, preoperative good cardiopulmonary, liver, and kidney function, tolerance to robotic or laparoscopic/open surgery, and enrollment in urban employee medical insurance or urban and rural resident medical insurance.

Exclusion criteria include patients with benign or non-adenocarcinoma rectal lesions, inability to receive curative surgical resection of rectal cancer lesions or the need for combined organ resection, with multifocal colorectal cancer, with familial adenomatous polyposis or inflammatory bowel disease, with other malignant tumors within the past 5 years or diseases deemed unsuitable for the study by the investigator, previous pelvic surgery history that may affect surgical procedures deemed by the investigator, with distant organ tissue metastasis (M1), with planned lateral lymph node dissection or non-one-stage anal-preserving surgery (such as abdominoperineal resection or rectal resection + proximal colon single-lumen colostomy Hartmann's procedure) or planned transanal total mesorectal excision (TaTME) or natural orifice specimen extraction surgery (NOSES).

The study will exam patients' economic (including direct medical costs, indirect medical costs, indirect costs), clinical (including perioperative safety, complications and oncological efficacy indicators), and quality of life indicators.

Direct medical costs will include the costs of medical health resources used by patients for diagnosis and treatment such as surgical fees, medication costs, and examination costs. Direct non-medical costs will include additional expenses such as transportation and accommodation for treating diseases. Indirect costs will include patients' and family members' losses of schooling, work, or wages due to illness. Perioperative safety indicators include intraoperative blood loss, conversion to open surgery, time to first flatus postoperatively, unplanned readmission within 30 days postoperatively, unplanned reoperation within 30 days postoperatively, and mortality within 30 days postoperatively. Additionally, the location and length of surgical incisions will be recorded, along with occurrences of wound infection, anastomotic leakage, and urinary dysfunction, etc.

The study will use the EQ-5D-5L to measure patients' quality of life and the preoperative anxiety scale to assess patient anxiety levels. Baseline characteristics such as demographic features and socioeconomic indicators (such as education and occupation) will also be collected. After enrollment, patients will be followed for 3 years, and the above information will be collected pre- and post-surgery, 1 month, 3 months, 6 months, 9 months, 12 months, 18 months, 24 months, 30 months and 36 months after surgery, respectively. Information will be collected from electronic health records in the hospital and questionnaire survey.

This study will use incremental cost-effectiveness analysis (ICEA) and incremental cost-utility analysis (ICUA) methods to evaluate the economic value of robotic surgery versus laparoscopic and open surgery.

How Will Medical Robot Effect the Death Rate of Surgery

By Ermo Chen*

A retrospective study is done to analysis the effect on death rate of robotic surgeries, investigating the changes of death rate with introducing medical robots into healthcare systems. This is part of the project of researches on medical errors. The analysis is done with two data sources, one is the service record from a market- dominating medical robot provider, and the other is a statistical result data from an info-tech provider covering thousands of hospitals in China. Results show that the medical robot can lead significantly reduce on death rate of surgery, which might mean medical robots could reduce medical errors. And that will be investigated further.

Prior works does not show coherent significantly benefit on surgeries with introducing medical robots (Borden et al. 2007; Alemzadeh et al. 2016), while in real world it does become more and more popular. More driving factors need to be excavated. Too few samples to draw reliable result beyond expectation, such as risk and uncertainty, in cohort studies. This force us to use larger data sets in a retrospective way.

We investigate the effect on death rate changes by introducing medical robots. Results show that the medical robot can lead significantly reduce on death rate of surgery. This is part of the project of researches on medical errors.

I. Data

Service record from a market-dominating medical robot provider, with all its service records in mainland China. It recorded the name of hospital, surgery date and category of surgery of each case.

Statistical records from an info-tech provider are provided by an inner statistical report, with samples covering 2007-2022 calendar years and 6252 hospitals in mainland China. Number of Samples, Death rate, Average Cost, Variance of Cost and In-hospital Days are reported for each hospital each month and each category of surgery or division. The location, level and grade of the hospitals are also accessible.

These two sources could be merged with hospital and date, making the analysis fea-

* School of Mathematical Sciences and PKU China Center for Health Economic Research, Peking University, No.5 Yiheyuan Road, Haidian District, Beijing, 100871 (email: chenermo@stu.pku.edu.cn).

sible. 6252 hospitals are covered in the analysis, containing 97 hospitals with medical robots using records, covering 28328/314152 = 9% of all the service record in robot provider. With a data filter, 4231 hospitals with 30936 hospital-quarters are finally used in drawing statistical conclusions.

II. Death Rate Modeling

The regression model in this section is

$$(1) \qquad DeathRate_{i,t} \sim Robot_{i,t} + X_i + I_t, \quad \omega = SampleSize_{i,t},$$

where we use two kinds of variables measuring the level of introducing robots, the number of cases done with robots (Num_of_Robot), and the rate of cases down with robots w.r.t. the sample size (Robot_Rate). This is because that the statistical record data is drawn on samples but not fully records, making the evaluation of robot rate not accurate enough. However, the robot rate is necessary to evaluate the level of effect beyond a signature judgement. So both of them are considered in the process of analysis.

Two kinds of fix effected for hospitals are considered. One is to use the unique ID of hospital directly, which is simple while constrained by some missing result in statistical result data. The other one is to use the province, level and grade instead, with may loss some information but more reliable. We check the result of both settings, for robustness and reducing endogeneity.

III. Result

Results of modeling surgery cases with Num_of_Robot are shown as below in Table 1.

TABLE 1—Num_of_Robot AND DEATH RATE

	Hospital Level, Robot Count			
Num of Robot	1.65E-06	1.12E-06	-6.19E-06	-2.12E-06
p-Value: Num of Robot	0.0838	0.2436	0.0000	0.0094
Fix Effect: Time		Yes	Yes	Yes
Fix Effect: Hospital				Yes
Fix Effect: Divisioin				
Fix Effect: Province			YES	
Fix Effect: Hospital Lv			YES	
Fix Effect: Hospital Grade			YES	
Num of Model Points	30,936	30,936	30,936	30,936
F-stats	2.9890	5.1351	100.2786	17.8164
R-squared	0.0001	0.0104	0.2454	0.7417

The result shows a significantly negative relationship between robot surgery count and death rate, under the control of fix effect of time and hospital (both directly and indirectly). Without the control of fix effect, especially the hospital effect, the result becomes complex. This is caused by the selection bias on introducing robots among hospitals, which is common as it is very expensive.

Results of accounting amount of proportion of surgery cases done with robots w.r.t. sample cases are shown as below in Table 2.

TABLE 2—Robot_Rate AND DEATH RATE

	Hospital Level, Robot Count			
Num of Robot	2.27E-02	1.79E-02	-2.88E-02	3.10E-02
p-Value: Num of Robot	0.1020	1.79E-02	0.0184	0.0057
Fix Effect: Time		Yes	Yes	Yes
Fix Effect: Hospital				Yes
Fix Effect: Divisioin				
Fix Effect: Province			YES	
Fix Effect: Hospital Lv			YES	
Fix Effect: Hospital Grade			YES	
Num of Model Points	30,936	30,936	30,936	30,936
F-stats	2.6734	5.1401	99.6580	17.8172
R-squared	0.0001	0.0104	0.2454	0.7417

Similar results could be drawn from this analysis about proportion, while things change as the fixed effect is chosen directly using hospital ID. This is because that the data of robot service is full covered, but the statistical results are sampled. It then will disturb the evaluate of measuring real robot rate, as the denominator is not reliable.

IV. Conclusion

Results show that the medical robot can lead significantly reduce on death rate of surgery. This might mean medical robots could reduce medical errors. Effects on average cost, variance of cost and in-hospital days will be investigated further, and casual inference will be done by following works.

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Clinical Evaluation of Robot-Assisted Laparoscopic Radical Prostatectomy Based on Real-World Data

By Xin Yong, Zhen-hua Liu, Yu-jie Mao, Di-jia Wang, Qiang Dong, Bing-jie Luo, Ying Zhao, Xiao-dong Wang, and Lei Chen*

Radical prostatectomy stands as one of the preferred therapeutic interventions for local prostate cancer, with robot-assisted laparoscopic radical prostatectomy (RALP) garnering widespread attention in the medical community for its precision and minimally invasive nature. However, there is a lack of comprehensive assessments regarding the efficacy, safety, and cost-effectiveness of RALP. This retrospective study aims to conduct an in-depth analysis of RALP cases undertaken from 2017 to 2021 at West China Hospital of Sichuan University, employing Health Technology Assessment (HTA) methodologies that encompass surgical costs, clinical outcomes, and patient safety.

As the incidence of prostate cancer continues to climb, identifying treatment methods that are effective, safe, and economical has become a global medical challenge. Radical prostatectomy stands as one of the preferred therapeutic interventions for local prostate cancer, with robot-assisted laparoscopic radical prostatectomy (RALP) garnering widespread attention in the medical community for its precision and minimally invasive nature. However, there is a lack of comprehensive assessments regarding the efficacy, safety, and cost-effectiveness of RALP. This retrospective study aims to conduct an in-depth analysis of RALP cases undertaken from 2017 to 2021 at West China Hospital of Sichuan University, employing Health Technology Assessment (HTA) methodologies that encompass surgical costs, clinical outcomes, and patient safety. The research is designed to provide robust evidence for healthcare administrative bodies and hospitals in making equipment allocation decisions, optimizing the treatment pathway for prostate

* Yong: Equipment and Materials Department, West China Hospital, Sichuan University; Liu: Department of Urology, West China Hospital, Sichuan University; Mao: Equipment and Materials Department, West China Hospital, Sichuan University; Wang.D: Equipment and Materials Department, West China Hospital, Sichuan University; Dong: Department of Urology, West China Hospital, Sichuan University; Luo: Equipment and Materials Department, West China Hospital, Sichuan University; Zhao: Equipment and Materials Department, West China Hospital, Sichuan University; Wang.X: Institute of Hospital Administration, West China Hospital, Sichuan University; Chen(Corresponding Author): Department of Neurology, West China Hospital, Sichuan University (email: leilei_25@126.com).

cancer. The current main progress of the project is as follows:

(i) The research proposal and academic review materials have been submitted according to the requirements of the hospital's Biomedical Ethics Committee for the extraction and analysis of clinical patient-related data. Approval of West China Hospital Sichuan University Biomedical Ethics Committee (Approval No. 43, 2024) has been obtained in January 2024, allowing for the ethical data research of the project;

(ii) Following discussions with experts in the fields of urology, economics, and related areas, as well as considering existing hospital data, the research team is currently further optimizing and clarifying the evaluation dimensions and content of safety, effectiveness, and economic indicators. The consensus reached in the discussion is as follows:

- Traditional open surgery for radical prostatectomy is not prevalent, with limited surgical cases and insufficient data. This group will be removed;

- Regarding effectiveness and safety indicators, clinical staging holds significant subjectivity and is not required items in clinical case records, with insufficient data. This indicator will be removed. Various indicators including prostate volume, intraoperative blood transfusion rate, transfer surgery rate, surgical infection rate, functional assessment scale, positive surgical margin rate, and biochemical recurrence-free survival rate lack records or standardized recording, requiring further adjustments. Additionally, indicators including Gleason score from needle biopsy, underlying disease, intraoperative blood loss, drainage tube removal time, surgical complications, among others, lack complete records and require further adjustments. Pathology and laboratory-related data (such as pre- and post-operative hemoglobin levels) is suggested as indicators and it's easy to extract from existing clinical data.

- Regarding economic indicators, costs of equipment operation and maintenance cannot be accurately measured and holds minimal significance. It's suggested to focus more on postoperative related expenses (such as postoperative care, secondary surgical expenses, etc.).

Health Economics Study of Robots and Laparoscopy for Hepatocellular Carcinoma Resection

By Xiao Liang, Haijing Guan, Junhao Zheng, and Chenyue Yang*

To explore the clinical value and medical costs of robotic liver resection compared to laparoscopic liver resection, we retrospectively collected data from patients with hepatocellular carcinoma who underwent minimally invasive liver resection at Sir Run Run Shaw Hospital affiliated with Zhejiang University from January 2016 to July 2023, to analyze the cost-effectiveness of robotic liver resection versus laparoscopic liver resection for the treatment of hepatocellular carcinoma. A total of 277 patients were included in this study (175 in the laparoscopic liver resection group and 102 in the robotic liver resection group). After controlling for confounding factors using propensity score matching, a total of 162 patients (81 in each group) were included for further analysis. The results showed that compared to the laparoscopic liver resection group, the robotic liver resection group had less intraoperative bleeding, fewer postoperative complications, a lower conversion rate to open surgery, and better surgical safety. The robotic liver resection group had higher medical costs (82885.3 vs. 58643.8￥, p<0.001), however, the costs other than the surgery itself were significantly higher in the laparoscopic liver resection group. Furthermore, in high-difficulty liver resections, the cost difference between the two procedures decreased. For patients with hepatocellular carcinoma, robotic liver resection offers better surgical safety and higher medical costs compared to laparoscopic liver resection. However, other than the surgical costs, the other expenses associated with robotic liver resection are lower. Additionally, the increase in surgical difficulty narrows the cost gap between the two procedures.

I. Introduction

Robotic liver resection (RLR), as a new technology, may offer better surgical safety compared to laparoscopic liver resection (LLR), though it tends to be more costly. Therefore, whether using robotic resection for the treatment of hepatocellular carcinoma (HCC) is economically effective remains to be evidenced due to the current lack of re-

* Liang: Sir Run Run Shaw Hospital, Zhejiang University (email: 3190104362@zju.edu.cn); Guan: Beijing Tiantan Hospital, Capital Medical University; Zheng: Sir Run Run Shaw Hospital, Zhejiang University; Yang: Sir Run Run Shaw Hospital, Zhejiang University

lated proof.

II. Literature Review

Current health economics research related to robotic liver resection is rarely reported both domestically and internationally. A meta-analysis in 2022, which included four related pieces of literature, showed that the cost of RLR ($20,205.92) is significantly higher than that of LLR ($15,789.75). Cost has become a crucial factor limiting the implementation of RLR (Ciria et al. 2022). However, with the development of modern medicine, surgery aims not only to cure but also to improve the quality of life. In 2020, Mejia et al. reported on 214 cases of liver resection, noting that compared to LLR, RLR, despite being more expensive, resulted in shorter hospital stays, making it a better option for patients undergoing minor liver resections (Mejia et al. 2020). In contrast, a 2016 study by Chinese scholars, based on data from 39 patients undergoing robotic and laparoscopic left lateral liver section resection, indicated that for left lateral liver section resection, RLR was more expensive than LLR, but there was no statistically significant difference in efficacy and safety (Yin et al. 2016). Therefore, whether RLR can improve quality of life and be cost-effective remains a matter of debate.

The 2023 international guidelines on robotic liver resection pointed out that RLR has unique therapeutic value in liver-related diseases compared to LLR, and its cost-effectiveness warrants further study (Liu et al. 2023). In disciplines such as urology and colorectal surgery, studies have found robotic surgery to be cost-effective, or have pointed out the need to reduce costs to improve the application rate of robotics (Simianu et al. 2020; Song et al. 2022).

III. Methods

Conduct real-world research, retrospectively collecting data on inpatients diagnosed with HCC at Sir Run Run Shaw Hospital affiliated with Zhejiang University from January 2016 to July 2023. Patients were divided into RLR and LLR groups based on the type of surgery they underwent. On the basis of descriptive analysis, confounding factors were controlled through propensity score matching to explore the net benefits of different treatment methods on treatment outcomes and medical costs, and to conduct an economic evaluation. Subgroup analyses were carried out to explore the robustness of the research results.

Continuous variables with a normal distribution are described as mean ± standard deviation, while those with a skewed distribution are described as median (interquartile range), and categorical variables are described as frequency and percentage. Age, BMI, AFP, INR, ALB, AST, TBIL, Child-Pugh classification, vascular invasion, difficulty of operation, and ASA classification were included as covariates in the model for fitting, and propensity scores were calculated for nearest neighbor matching. PSM analysis was conducted using SPSS version 25.0. Patients were divided into four subgroups based on IWATE surgical difficulty grading as “Low”, “Intermediate”, “Advanced”, and “Expert” for subgroup analysis.

IV. Results

After screening based on inclusion and exclusion criteria, a total of 277 patients were included in this study, divided into LLR group (175 cases) and RLR group (102 cases) according to the surgical method. Before propensity score matching, the LLR group had significantly higher intraoperative blood loss (p=0.000), intraoperative transfusion rate (p=0.045), postoperative complication rate (p=0.003), intraoperative conversion rate to open surgery (p=0.001), length of hospital stays (p=0.001), and postoperative hospital stay (p=0.001) compared to the RLR group. The total hospitalization cost (p=0.000), out-of-pocket costs (p=0.000), and surgical costs (p=0.000) in the LLR group were significantly lower than those in the RLR group, while drug costs (p=0.000), examination costs (p=0.010), nursing costs (p=0.001), and material costs (p=0.000) were significantly higher in the RLR group. After propensity score matching to balance baseline indicators, 162 patients (81 in each group) were included for further analysis. The results showed that intraoperative blood loss (p=0.002), postoperative complication rate (p=0.043), length of hospital stay (p=0.005), and postoperative hospital stay (p=0.000) in the LLR group were significantly higher than those in the RLR group. The total hospitalization cost (p=0.000), out-of-pocket costs (p=0.000), surgical costs (p=0.000), and other costs (p=0.004) in the LLR group were significantly lower than those in the RLR group, while drug expenses (p=0.000), examination costs (p=0.010), nursing costs (p=0.001), and material costs (p=0.000) were significantly higher in the RLR group. (Table 1)

Subgroup analysis was conducted using IWATE surgical difficulty grading as a covariate. The results showed that within the “Low”, “Intermediate”, and “Advanced” subgroups, the hospitalization costs of the LLR group were significantly higher than those of the RLR group (Low: p=0.000; Intermediate: p=0.003; Advanced: p=0.001). However, in the “Expert” subgroup, there was no significant difference in hospitalization costs between the LLR and RLR groups (p=0.325). Additionally, it can be observed that as the surgical difficulty increased, the difference in hospitalization costs between the RLR and LLR groups narrowed.

Table1. Outcome indicators of LLR and RLR groups before and after PSM

Outcome	Before PSM (n=277)			After PSM (n=162)		
	LLR (n = 175)	RLR (n = 102)	p value	LLR (n=81)	RLR (n=81)	p value
Optime (IQR), min	160 (115)	166 (106)	0.263	180(130)	160 (113)	0.134
Status_of_surgical_margin, n(%)			0.494			1
R0	166 (98.2)	98 (96.1)		79(98.8)	79(97.5)	
R1_or_R2	3(1.8)	4(3.9)		1(1.3)	2(2.5)	
Hemorrhage_during_operation (IQR), mL	100.0 (350.0)	50.0 (63.0)	<0.001	100.0 (225.0)	50.0 (75.0)	0.002
Intraoperative_transfusion, n(%)	33(18.9)	10(9.8)	0.045	12(14.8)	8(9.9)	0.339
Complication, n(%)	35(20.0)	7(6.9)	0.003	16(19.8)	7(8.6)	0.043
ClavienDindo, n(%)			0.006			0.062
No	140(80.0)	95(93.1)		65(80.2)	74(91.4)	
I_or_II	25(14.3)	6(5.9)		10(12.3)	6(7.4)	
III_or_IV_or_V	10(5.7)	1(1.0)		6(7.4)	1(1.2)	
Open_conversion, n(%)	20(11.5)	0(0.0)	0.001	5(6.2)	0(0.0)	0.069
Re_operation, n(%)	0(0.0)	0(0.0)	/	0(0.0)	0(0.0)	/
Mortality_in_hos, n(%)	0(0.0)	0(0.0)	/	0(0.0)	0(0.0)	/
PostopStay (IQR), day	6.0(3.0)	5.0(3.0)	0.001	6.0(3.0)	5.0(3.0)	0.005
Re_admission_30days, n(%)	3(1.7)	1(1.0)	1	2(2.5)	1(1.2)	1
LOS (IQR), day	13.0(6.0)	9.5(6.0)	<0.001	12.0 (6.0)	10.0(4.0)	<0.001
Hospitalization_cost (IQR), ¥	57150.9 (31989.2)	81432.5 (16289.2)	<0.001	58643.8 (30728.6)	82885.3 (14883.9)	<0.001
Out_of_pocket_payment (IQR), ¥	16875.0 (13102.7)	50333.4 (11358.2)	<0.001	15972.7 (14057.0)	50706.2 (10843.8)	<0.001

Drug_cost (IQR), ¥	15879.4 (12239.8)	9955.6 (6319.6)	<0.001	16517.6 (12034.57)	9975.0 (6255.6)	<0.001
Surgery_cost (IQR), ¥	6916.0 (1532.3)	43424.9 (1089.4)	<0.001	6616.0 (1316.4)	43424.9 (1240.4)	<0.001
Examine_cost (IQR), ¥	1260.0 (1223.0)	1160.0 (1079.8)	0.01	1365.0 (1265.0)	1115.0 (943.0)	0.001
Nursing_cost (IQR), ¥	1164.0 (642.0)	989.6 (507.25)	0.004	1174.0 (722.5)	988.6 (475.2)	0.012
Material_cost (IQR), ¥	21113.4 (15925.4)	12094.4 (7195.0)	<0.001	21565.4 (16942.8)	12069.4 (8195.4)	<0.001
Other_cost (IQR), ¥	386.0 (540.0)	486.5 (605.2)	0.054	341.0 (401.4)	535.0 (586.5)	0.004

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Clinical Efficacy and Health Economic Evaluation of Robot-Assisted Hip and Knee Joint Replacement Based on Real-World Data

By Beini Lyu, Yang Song, and Yixin Zhou*

Artificial joint replacement is the most effective treatment for end-stage hip and knee arthritis. Compared to traditional surgical procedures, robot-assisted hip and knee joint replacement offers advantages such as high precision in positioning, high consistency, reduced postoperative pain, and early functional recovery, potentially improving patient prognosis. However, the costs associated with robot-assisted hip and knee joint replacement are higher than traditional surgery, necessitating a systematic health technology evaluation its value. This study is based on individual patient-level data and include patients undergoing total knee and total hip joint replacement. The study uses electronic medical record data and active follow-up to exam the impact of robot-assisted surgery (vs. traditional surgery) on patients' clinical outcomes, quality of life, and medical expenses. The study uses cost-effectiveness analysis to economic value of robot-assisted hip and knee joint replacement.

I. Background

With the continuous aging of the population in China, the burden of hip and knee arthritis is steadily increasing (Long et al. 2020). By the end of 2019, approximately 120 million people in China were estimated to have hip and knee arthritis (Kim et al. 2020). Artificial joint replacement is the most effective treatment for end-stage hip and knee arthritis. Traditional hip and knee joint replacement surgery faces challenges such as insufficient surgical precision, lack of digital intelligent tools, and high revision failure rates. Robot-assisted hip and knee joint replacement, with its high precision in positioning and consistency, reduced postoperative pain, and early functional recovery, has attracted widespread attention (Yang et al. 2024; Subramanian et al. 2019). Early studies have shown that compared to traditional surgery, robot-assisted joint replacement surgery has advantages such as accurate bone cutting assistance, individualized implant placement, better protection of soft tissues around the knee joint, reduced use of analgesics, and

* Lyu: Institute for Global Health and Development, Peking University (e-mail: blyu@pku.edu.cn); Song: Beijing Jishuitan Hospital, Capital Medical University; Zhou: Beijing Jishuitan Hospital, Capital Medical University.

shortened hospital stays, but also shortcomings such as prolonged operation time (Shao et al. 2023; Subramanian et al. 2019; Yang et al. 2024). Despite the potential improvement in patient prognosis with robot-assisted joint replacement, its medical costs are significantly higher than traditional surgery, posing a challenge to balancing limited medical resources and improving patient health. Reimbursement policies about robot-assisted joint replacement are developing but there is currently a lack of systematic economic evaluations for robot-assisted joint replacement in China, which hinders the formulation and adjustment of key policies. By utilizing real-world patient data undergoing hip and knee joint replacement, this study will compare the clinical outcomes, quality of life, and costs of robot-assisted and non-robot-assisted hip and knee joint replacement, aiming to clarify the cost-effectiveness of robot-assisted hip and knee joint replacement.

II. Brief Methods

The study is a retrospective cohort study. The study includes patients who aged 21-80, with osteoarthritis or joint deformity, underwent robot-assisted or traditional total knee/total hip joint replacement surgery at the Jishuitan Hospital Orthopedics Department from August 2020 to December 2023, and with ASA scores of I-II. Patients who are pregnant, undergoing knee joint revision, have severe flexion deformity (>20°), severe varus or valgus deformity (>20°), rheumatoid arthritis, or infectious arthritis are excluded.

Patients' demographic characteristics (such as age, gender), surgical indications, complications (including hypertension, diabetes, coronary heart disease, osteoporosis), surgical-related information (including surgical site, duration, intraoperative blood loss), medical expenses (total hospitalization costs, surgical costs, diagnosis and treatment costs, examination costs) are extracted from electronic medical records. Radiological assessment such as hip-knee-ankle angle, distal femoral lateral angle, and proximal tibial medial angle is performed by orthopedics. The study conducts telephone follow-ups to ascertain whether patients experience events such as prosthesis revision or prosthesis loosening. Additionally, the study measures patients' quality of life using EQ-5D-5L and assess joint function and patient satisfaction using WOMAC scores, both of which are completed via telephone follow-ups.

For data analysis, study conducts separate analyses for total knee and total hip joint replacement. Descriptive analysis will first be conducted to compare clinical outcomes, quality of life and costs among patients who received robot-assisted and those who received traditional hip and knee joint replacement surgery. Survival analysis will be used to evaluate the impact of different surgical procedures on risk of joint revision, a two-step model will be used to assess the impact of surgical procedures on medical expenses, and linear regression analysis will be used to evaluate the impact of surgical procedures on joint function and satisfaction. To balance the potential differences between the two groups of patients, propensity scores and inverse probability weighting will be used. The study will calculate the incremental cost-effectiveness ratio (ICER) between the robot-assisted hip and knee joint replacement group and the traditional surgery group to determine the economic value of robot-assisted hip and knee joint surgery.

III. Preliminary Results

Through preliminary data cleaning, the study included 250 patients undergoing robot-assisted total knee joint replacement surgery, with a mean age of 66.9 (7.5) years. Patients who underwent non-robot-assisted total knee joint replacement surgery were matched 1:1 based on age and gender, and data cleaning and patient follow-up are currently underway. The study will further include patients undergoing total hip joint replacement surgery.

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Acceptance, Adoption, and Use of Surgical Robots in China: Distribution, Variation, and Subjective Attitudes

By TING CHEN, LU AO, YUHANG PAN, CHUFAN ZHOU, AND JAY PAN*

The cost-effectiveness differences in the use of surgical robots vary significantly across different providers (institutions, physicians), procedures, and patient characteristics. Understanding the current distribution and patterns of technology is fundamental to the design of Health Technology Assessment (HTA) and related health economic studies. This study adopts a primary structural approach of "current status description-distribution differences-differential analysis." Currently, a spatiotemporal description method was employed to demonstrate the partial usage and distribution differences of Da Vinci surgical robots in China. Based on literature review and expert consultation, a preliminary subjective survey scheme has been designed, establishing a theoretical foundation of subjective attitudes among decision-makers, surgeons, and patients, along with a questionnaire outline.

I. Introduction

Innovation is seen as a necessary condition for progress. Since the latter half of the last century, there has been rapid technological innovation and progress in the field of healthcare, providing a strong foundation for the construction and enhancement of healthcare systems (Gelijns 1990). However, utilization of technology remains inadequate in health care, according to the data of U.S. health care, comparing some other industries, the industry has been growing faster than the overall economy, but where the productivity growth has been minimal, one of the reasons is the lagged use of technology (Sahni et al. 2017).

The use and demand for robotic medical and surgical platforms is increasing and new technologies are continually being developed (Peters et al. 2018), but its application in

* Chen: School of Public Health, Sichuan University / West China Fourth Hospital, Sichuan University HEOA Group (email: chenting_723@163.com); Ao: School of Public Health, Sichuan University / West China Fourth Hospital, Sichuan University HEOA Group (email:2352480696@qq.com); Pan.Y: Institute for Global Health and Development, Peking University (email:yhpan@pku.edu.cn); Zhou: School of Public Health, Sichuan University / West China Fourth Hospital, Sichuan University HEOA Group (email: 202322404001@stu.scu.edu.cn); Pan.J: School of Public Health, Sichuan University / West China Fourth Hospital, Sichuan University HEOA Group (email: panjie.jay@scu.edu.cn).

healthcare often faces obstacles(Randell et al. 2019; Szabó, Őrsi, and Csukonyi 2024), leading to uneven distribution of its technological diffusion and suboptimal utilization of its benefits(Miraldo et al. 2019). Apart from the limitations inherent to the technology itself, factors such as demographics, socio-economic status, and psychological aspects of the adopters or users are considered significant constraints influencing the adoption of surgical robots and their ability to fully leverage their clinical, economic, and societal benefits (Randell et al. 2019), and also results in varied cost-effectiveness of the technology across different surgical procedures and study populations. (Abrishami, Boer, and Horstman 2020).

China is still in the early stages of applying surgical robots, and effectively managing and promoting the development of surgical robots is an important issue. Currently, the application status, distribution characteristics, and equity among different populations regarding the use of surgical robots in China are not well understood and severely lack empirical evidence. Understanding the distribution status and differential characteristics of surgical robots is the basis for the design of Health Technology Assessment (HTA) and related health economic studies. At the same time, analyzing the subjective attitudes and acceptance of surgical robots by different stakeholders can reflect the market laws and causes from the perspective of the "real world", helping to improve the efficiency and fairness of medical procedures and provide evidence for the development of "human-centered" surgical robots. This project aims to understand the acceptance, adoption, and use of surgical robots in China, considering distribution, variation and subjective attitudes from the perspectives of medical institution decision-makers, surgeons, and patients. It considers fairness at the regional and population levels and analyzes the macro, meso, and micro influencing factors affecting the application of technology by various stakeholders, providing empirical evidence and suggestions for the management of relevant medical and health markets and the promotion of technology.

II. Method

Currently, this study employed spatial-temporal descriptive statistical methods to showcase partial usage patterns and distribution disparities of Da Vinci surgical robots in China. The data utilized primarily comprise records of Da Vinci surgical robot technology usage from 2007 to 2022 in China. The demographic equity was explored by provinces regarding the emerging technology representative, the Da Vinci surgical robot technology. Based on literature review and expert consultations, a preliminary subjective survey plan has been designed, incorporating theoretical foundations of subjective attitudes from decision-makers, surgeons, and patients, along with a questionnaire outline, awaiting subsequent research and further analysis.

III. Result

A. doption and use of surgical robots in China

Since the introduction of the Da Vinci surgical robot in China in 2007, up until the end of the second quarter of 2022, a total of 269 Da Vinci surgical robots have been adoption in the country. These robots have been used in 314,152 surgeries. Both the number of devices and the usage have shown an upward trend over the years, particularly since the mid to late 2014 period when the rate of usage notably accelerated, demonstrating an exponential growth trend (excluding the years 2019-2020 affected by the COVID-19 pandemic), as depicted in Figure 1.

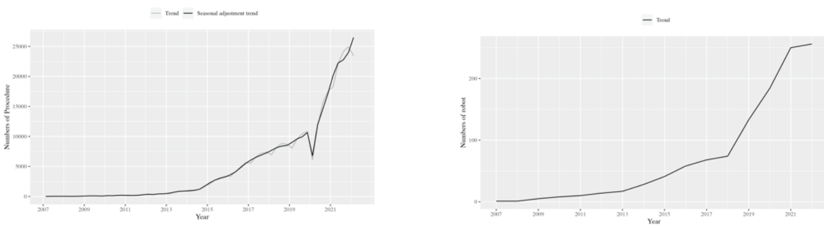

FIGURE 1. THE TREND OF THE ADOPTION AND UTILIZATION OF DA VINCI SURGICAL ROBOTS FROM 2007 TO 2022 IN CHINA

The utilization of Da Vinci surgical robots in various provinces of China shows significant distribution disparities. Initially, it was primarily used in economically developed regions such as Beijing, Shanghai, and Guangdong. Gradually, it diffused to less developed inland areas. However, as of mid-2022, provinces such as Xinjiang, Qinghai, and Ningxia still had relatively low usage rates, and there has been no introduction of the technology in Tibet.

As of the end of the second quarter of 2022, a total of 229 institutions in China have adopted Da Vinci surgical robots, comprising 228 hospitals and 1 medical center. Among these, 226 are tertiary hospitals (99.12%), 223 are public hospitals (97.81%), and 219 are research-oriented hospitals (96.05%). Among all surgical cases, urological surgery is the most common, accounting for 45.58%, followed by general surgery (25.82%), thoracic surgery (14.23%), and obstetrics and gynecology (11.37%). The most performed types of procedures are prostatectomy (18.49%), partial nephrectomy (13.05%), and lung resection (10.37%).

B. Theoretical Framework of Surgical Robot Technology Adoption

The study constructs a theoretical framework based on systematic literature review(Szabó, Őrsi, and Csukonyi 2024; Compagni, Mele, and Ravasi 2015; Randell et al. 2019; Abrishami, Boer, and Horstman 2014; Maynou et al. 2022; Sundaresan, Boysen, and Nerkar 2023; Menchik 2020) and expert consultations to analyze the factors influencing the adoption of Da Vinci surgical robot technology among institutional decision-makers, surgeons, and patients, incorporating both objective conditions and subjective attitudes of relevant stakeholders. Based on this theoretical framework, the study has developed preliminary interview guidelines and questionnaires for decision-makers, surgeons, and patients. Utilizing descriptions of the spatial-temporal distribution of technology usage and drawing upon innovation diffusion theory, the study will select one "technology pioneer" institution (introduced the surgical robot technology before 2014), one "technology conservative" institution (introduced the technology after 2014), and one "non-adopter" institution (a tertiary hospital yet to adopt the technology) for further investigation.

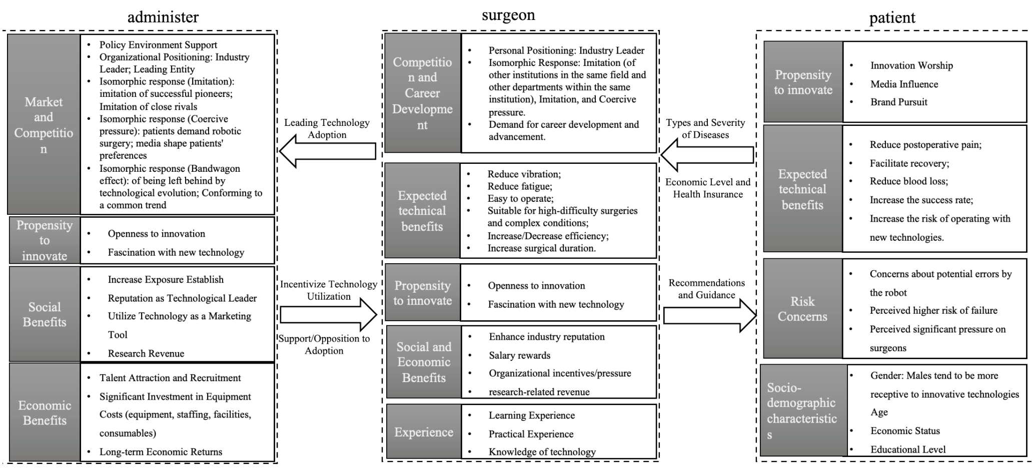

FIGURE 2 THEORETICAL FRAMEWORK DIAGRAM OF FACTORS INFLUENCING THE ADOPTION OF SURGICAL ROBOT TECHNOLOGY

IV. Summary and Further Plans

Currently, this study has conducted preliminary analysis on the usage status and distribution disparities of Da Vinci surgical robots in China. Systematic literature reviews and partial expert consultations have been completed, and a theoretical framework and investigation plan for studying influencing factors have been constructed. Next, the study will further analyze the distribution disparities and equity, explore patterns, and causes in conjunction with the characteristics of demand-side patients, and conduct field research to collect primary data. This will provide an evidence base for policy formulation related to surgical robots' research in China.

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Robot Adoption in Chinese Hospitals

By KWAN TING LEUNG, AND YUHANG PAN *

Due to its unprecedent economic development and increasingly growing demands, China has become one of the fastest-growing markets for the surgical robotics developer. This short article briefly reviews the technology adoption of da Vinci surgical system (da Vinci RAS) in Chinese hospitals, especially at the hospital department level.

Due to its unprecedent economic development and increasingly growing demands, China has become one of the fastest-growing markets for the surgical robotics developer. This short article briefly reviews the technology adoption of da Vinci surgical system (da Vinci RAS) in Chinese hospitals, especially at the hospital department level. As of 2022, da Vinci RAS was recognized as the largest provider of robotic-assisted surgical (RAS) technology training to be accredited2, and nearly 7000 da Vinci RAS have been installed in more than 70 countries, with more than 10 million minimally invasive robotic surgical procedures performed (Xue and Liu 2022).

The da Vinci surgical system was first introduced in China in 2006, where it was adopted at Chinese PLA General Hospital. Over the period from 2006 to 2023, a total of 284 Chinese hospitals have implemented the da Vinci RAS system. This technology has then been utilized by approximately 2,300 surgeons among a diverse range of surgical procedures. These surgeons have performed over 180 kinds of procedures, with the highest volume observed in Urology at around 150 thousand procedures.

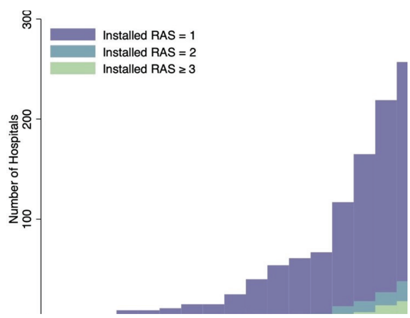

FIGURE 1. NUMBER OF CHINESE HOSPITALS WITH DA VINCI RAS

* Leung: Institute for Global Health and Development, Peking University (email: kwanting@stu.pku.edu.cn); Pan (Corresponding Author): Institute for Global Health and Development, Peking University (email: yhpan@pku.edu.cn). We thank Da Vinci for providing the market data. All errors are our own

[1]See https://isrg.intuitive.com/news-releases/news-release-details/intuitive-becomes-largest-robotic-assisted-surgery-provider-be

The adoption of da Vinci systems in Chinese hospitals encompasses four distinct models: DaVinci SP, DaVinci S, DaVinci Si, and DaVinci Xi. Our focus lies in examining the inaugural procedures performed using the da Vinci system within each category and across various hospital-department pairings. Figure 1 depicts the prevalence of da Vinci RAS systems across Chinese hospitals. Two notable periods of growth are observed. The first eye-catching growth occurred in 2014, where the number of hospitals with the da Vinci system nearly doubled. The second substantial growth took place around 2019, resulting in a rise from 69 hospitals to 119 hospitals with da Vinci systems.

Figure 2 illustrates the time lag between the installation of the da Vinci RAS system and its initial application across various surgical departments. The data suggest that General Surgery and Urology departments show a short interval from system installation to operation, possibly due to the high demands and immediate applicability of the da Vinci RAS for procedures common to these fields. The da Vinci RAS system is leveraged for an extensive array of procedures. For Urology, it can perform oncological management of prostate, kidney, and bladder cancers. In the sphere of General Surgery, the RAS system is for intricate removal of gastrointestinal malignancies, including gastric and colorectal cancers. Thoracic Surgery harnesses the advanced capabilities of the RAS for conditions like lung and esophageal cancers. For Gynecology, the da Vinci can be used to hysterectomies and managing gynecologic cancers. Building upon the classification initiated in Figure 2, the analysis extends to the level of hospital departments, incorporating additional specialties such as Pediatrics, Gastroenterology, Hepatobiliary Pancreatic, and Thyroid. As presented in Figure 3, only the Thyroid department exhibited a notable delay between the installation of RAS systems and their operational use, suggesting a latent phase of adoption for certain specialties.

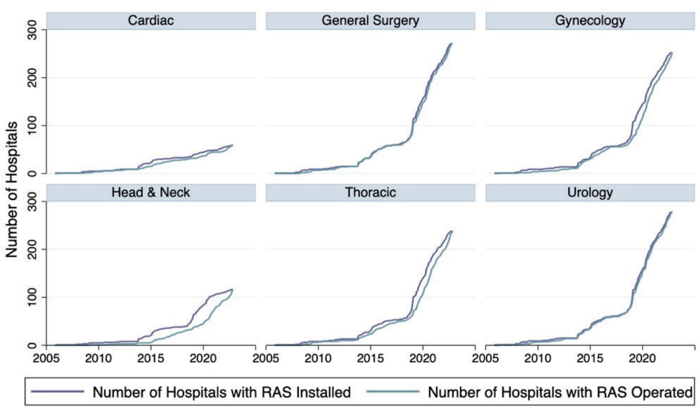

Figure 2. Installation and Operation of RAS by Category

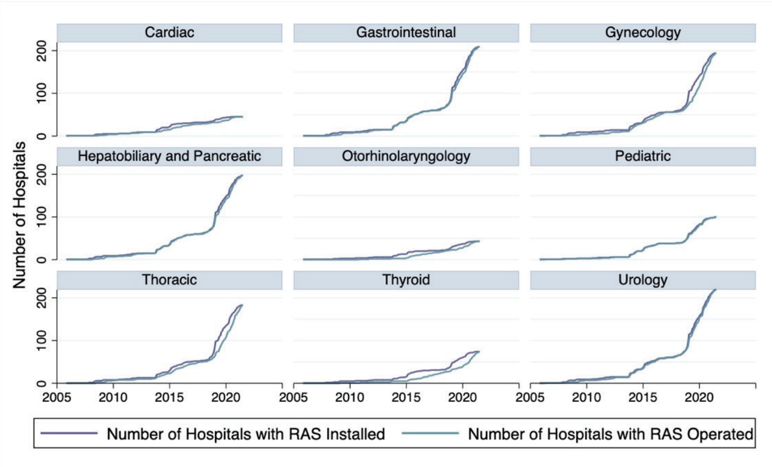

FIGURE 3. INSTALLATION AND OPERATION OF RAS BY HOSPITAL DEPARTMENTS

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Does Robotic Surgery Help Reduce the Economic Burden of Malignant Tumors in the Pancreas? A Cost-of-Illness Study

By Ziting Wu , Yin Shi, and Xiuping Zhang*

Compared to open surgery, laparoscopic surgery and robotic surgery have the advantages of causing less trauma to the human body and allowing for faster postoperative recovery. Compared to laparoscopic surgery, robotic surgery offers benefits such as clearer surgical views, more flexible robotic arms, and better feature for tremor filtration, which are conducive to delicate operations. However, the high cost of robotic surgery makes it uncertain whether it contributes to reducing the overall economic burden. This study aims to assess from the perspectives of medical institutions, and the society: the disease economic burden of robotic-assisted, laparoscopic and open surgeries on pancreatoduodenectomy for the treatment of pancreatic cancer. In this study, a retrospective cross-sectional design was utilized. Patients with pancreatic cancer who underwent pancreaticoduodenectomy at General Hospital of the People's Liberation Army of China between 2006 and December 2023 were included. The direct costs and indirect costs will be collected by Hospital Information System and questionnaire. Data retrieval and analysis are currently in progress.

I. Data Collection

For clinical diagnosis, treatment, surgical, and in-hospital cost information, this study plans to collect and analyze data by accessing the internal system of the cooperating hospital, the General Hospital of the People's Liberation Army of China (301 Hospital), under its authorization.

Currently, the cooperation center, 301 Hospital, has completed the agreement signing and ethical approval. The data application approval has been granted, and we are cur-

* Wu (Corresponding Author): Institute for Global Health and Development, Peking University, Beijing, China 100871 (email: wuziting@pku.edu.cn); Shi: Department of Pharmacy & National Clinical Research Center for Geriatric Disorders, Xiangya Hospital Central South University, Changsha, Hunan Province, China 410008, and Institute for Global Health and Development, Peking University, Beijing, China 100871(email: shiyin910515@csu.edu.cn); Zhang: Hepato-Biliary-Pancreatic Surgery, Chinese People's Liberation Army (PLA) General Hospital, Institute of Hepatobiliary Surgery of Chinese PLA, and Key Laboratory of Digital Hepatobiliary Surgery, PLA (email: xiupingzhang@aliyun.com).

rently waiting for the Information Department of 301 Hospital to retrieve relevant data on in-hospital costs.

II. Follow-up Method

This study plans to use electronic questionnaires, hiring survey personnel to complete the relevant electronic questionnaires using personal mobile devices to obtain outpatient medical costs, direct non-medical expenses, and indirect costs. The study will investigate the cost information from admission to the survey date within 0-5 days after discharge, and the cost information for the past 30 days within 30-35 days, 60-65 days, and 90-95 days after discharge for the selected samples.

After preliminary communication with 301 Hospital, the above follow-up is proposed to be implemented by hospital graduate students, with the Peking University team responsible for training on the questionnaire content.

III. Expansion of Research Centers

After communicating with 301 Hospital, it is proposed to further expand the research centers based on the preliminary analysis of retrospective data from 301 Hospital to increase the national representativeness of the study samples. The research team will further negotiate and determine the method of center expansion in the future.

The preliminary plan includes:

First, adding one to two research centers with a large volume of surgeries, which has the advantage of covering a large proportion of robotic surgery samples for the pancreatic cancer in China, resulting in better national representativeness of the study results. However, the cooperation threshold for such research centers is high.

Second, adding several research centers with an average volume of surgeries, which has the advantage of being able to cooperate with research centers in a relatively short time and helps evaluate the cost differences of robotic surgery in hospitals of different levels. However, the representativeness of the samples from such research centers is limited.

AI and Career Barriers in Surgery Departments: A Short Literature Background

By YUHANG PAN, JUNJIAN YI, AND QINGYUAN ZHOU *

Women face career barriers in many fields. In this short article, we review the attributions of these barriers and briefly summarize a series of previous studies on career barriers for women. Finally, the article explores how artificial intelligence can help address career barriers for women in the surgical industry.

Females encounter career barriers in many fields. These barriers can manifest in various forms, such as gender bias, stereotypes, limited access to leadership positions, and wage discrepancies (e.g., Bjerk 2008; Blau and Kahn 2017; Hospido, Laeven, and Lamo 2022; Lazear and Rosen 1990; Sloane, Hurst, and Black 2021; Winter-Ebmer and Zweimuller 1997; Zhang et al. 2021). These barriers can be attributed to both the demand and supply sides of the labor market. On the demand side, women suffer from preference-based and belief-based discrimination. Preference-based discrimination suggests that discrimination stems from inherent preferences, as employers have a distaste for certain groups, leading them to refuse to hire or only offer wages below their productivity level (Becker 1957). Belief-based discrimination comprises accurate statistical discrimination and inaccurate statistical discrimination, which stem from incomplete information available to employers regarding the true productivity of workers. As a result, employers rely on statistical inferences based on observable characteristics associated with workers' social groups, often resulting in discriminatory treatment of individuals from disadvantaged groups (Aigner and Cain 1977; Arrow 1985; Bohren et al. 2023; Phelps 1972).

On the supply side, the lack of female role models and cultural barriers hinder females from majoring and succeeding in male dominated fields (Jayachandran 2021; Porter and Serra 2020). For example, in Porter and Serra (2020)'s RCT, students in introductory economics classes are randomly exposed to successful and charismatic women who had majored in economics at the same university. They document a significant impact on female students' enrollment in further economics classes, leading to an increase in the

* Authors contribute equally and are ranked in alphabetical order. Pan: Institute for Global Health and Development, Peking University (email: yhpan@pku.edu.cn); Yi: National School of Development and Institute for Global Health and Development, Peking University (email: junjian@nsd.pku.edu.cn); Zhou: School of Economics, Peking University (email: qingyuanzhou.econ@gmail.com). All errors are our own.

likelihood of majoring in economics by 8 percentage points. Bertrand et al. (2021) find that the gender identity — in particular, an aversion to the wife's income exceeding the husband's — impacts the wife's labor force participation and division of home production. Goussé, Jacquemet, and Robin (2017) find that in more conservative families, women will dedicate more time to home production compared with the liberal ones. Adda, Dustmann, and Stevens (2017) suggest that fertility intrigues loss of skills, lost earnings, and selection into more child-friendly occupations.

Surgery departments are among the fields where women perhaps face one of the most severe career barriers (Schizas et al. 2022; World Health Organization 2019). According to the investigation of the Chinese College of Surgeons across 30 provinces, municipalities, and autonomous regions in 2019, females comprise only 6.04% of all surgeons (Bai 2021). Even in developed countries, this proportion remains low, ranging from 10% to 20% (Burgos and Josephson 2014). As highlighted by Schizas et al. (2022), despite the increasing numbers of female medical students, surgery remains male-dominated. By surveying a group of female surgeons, Epstein (2017) shows a limited representation of female surgeons in department chair roles or as full professors within academic institutions. To investigate the underlying factors contributing to these career barriers, some studies have utilized surveys to gauge supply-side beliefs. Zhou et al. (2022) reveal that a majority of female respondents who are uninterested in pursuing a surgical career believe that tutors tend to favor male candidates during the recruitment process. Male dominance within the field is cited as a primary reason by nearly all respondents who perceive females as unsuitable for surgery. Richardson and Redfern (2000) and Gargiulo, Hyman, and Hebert (2006) also argue that women are deterred from entering the surgery departments owing to a lack of role models in the field and the perception of surgery as an "old boys' club. Additionally, the perceptions of inability to have a good work-life balance as well as the requirement of physical strength also impede medical students from pursuing a career in the field of surgery (Rohde, Wolf, and Adams 2016; Bai 2021). Therefore, misperceptions about the job, the employer and oneself all lead to gender bias in the career choice as a surgeon. Another concern is the higher rates of infertility and pregnancy complications of female surgeons than the general population (Anderson and Goldman 2020). Some other studies summarize key challenges for women in surgery using qualitative methods. For example, Schizas et al. (2022) and Stephens et al. (2020) categorize the career barriers into gender discrimination and harassment, academic advancement, leadership, work- life imbalance, physical demands, pregnancy difficulties and gender pay gap. However, female surgeons may have similar or even better surgical outcomes compared to their male colleagues (Tsugawa et al. 2018; Wallis et al. 2017). For instance, Wallis et al. (2017) indicate that there is no evidence that the length of stay, complications, and readmission rates differ between patients treated by male surgeons and female surgeons, while male surgeons' patient tend to have the 30-day mortality rates. Additionally, Roter and Hall (2004) find that medical visits with female physicians are, on average, two minutes longer than those of male physicians, during which female physicians engage in significantly more patient-centered communication. Female physicians also engage in more active partnership behaviors, positive talk, psychosocial counseling, psychosocial question asking, and emotionally focused talk.

Skill-biased technological changes could alter the existing career barriers for females via multiple ways. First, technological advancement can influence the transformation of gender norms, thereby lowering the cultural barriers for females. However, usually gender norms take time to change. Existing literature primarily focuses on the long-run impact of agricultural technologies on the gender division of labor, and hence gender roles. In the seminal work of Boserup (1970), she argues that men have comparative advantages over women in terms of upper body and grip strength in engaging in the plough agriculture. Therefore, men historically play a more dominant role in breadwinning, leading to the gender gap in today's labor market. Alesina, Giuliano, and Nunn (2013) causally estimate the differential impacts of labor-intensive shifting agriculture and capital-intensive plough agriculture on outcomes related to employment, politics, entrepreneurship, and attitudes towards gender inequality among women. Similarly, Xue (2016) explores the relationship between the adoption of weaving technologies during China's cotton revolution and a lasting change in the biased belief regarding women's agency and abilities. These studies shed light on the influence of technological changes on gender dynamics and societal perceptions. With the introduction of surgical robots, physical strength is less needed in surgical procedures, thus undermining the comparative advantage of men and reshaping the beliefs. Second, robot adoption has been linked to increased labor productivity (Graetz and Michaels 2018). In the context of surgical procedures, the utilization of robotic technology could lead to shorter operation durations, potentially allowing women to achieve a better work-life balance. This, in turn, may facilitate greater female participation and entry into surgery departments.

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Cost-Effectiveness of Da Vinci Robotic-Assisted Thoracoscopic Surgery for Operable Early-Stage Non-small Cell Lung Cancer in China

By Tianfu Gao*

Lung cancer is the leading cause of cancer-related death in China with the tremendous disease and economic burden. Non-small cell lung cancer (NSCLC) accounts for approximately 85% in lung cancer patients, the gold standard treatment is surgical resection, including thoracotomy and minimally invasive surgery. The Da Vinci robotic surgery system offers clinical advantages over traditional thoracoscopy. This study conducted a partitioned survival model to evaluate the cost-effectiveness of Da Vinci robotic-assisted thoracoscopic surgery (RATS) compared to video-assisted thoracoscopic surgery (VATS) in early-stage NSCLC from healthcare system perspective.

I. Background

Lung cancer is the leading cause of cancer-related death in China. In 2022, approximately 870,000 new lung cancer patients with 760,000 deaths in China, ranking the first in the world (Xia et al. 2022; Cao et al. 2019). In 2020, the economic burden of lung cancer patients in China was approximately 29.1 billion USD, accounting for 0.121% of the country's GDP, and showing an increasing trend year by year (Liu et al. 2021). Non-small cell lung cancer (NSCLC) accounts for approximately 85% in lung cancer patients. The "Non-Small Cell Lung Cancer Diagnosis and Treatment Guidelines 2023" issued by the Chinese Society of Clinical Oncology recommend that for stage I and II NSCLC patients, the gold standard treatment is surgical resection, including thoracotomy and minimally invasive surgery. With the advancement of minimally invasive surgical techniques, lung cancer surgery has transitioned from traditional thoracotomy to thoracoscopic surgery. However, thoracoscopic surgery still has limitations for complex lung cancer cases. The Da Vinci robotic surgery system, with three-dimensional optics and multi-angle robotic arm operation, offers advantages over traditional thoracoscopy such as less intraoperative bleeding, more thorough lymph node dissection, lighter post-operative pain, and better prognosis (Yang et al. 2017; Nguyen et al. 2020; Nelson et al. 2019).

* Tianjin Medical University Cancer Institute and Hospital (email: tianfugary@163.com).

Da Vinci robot is widely recognized as an innovative medical technology in clinical practice, but the high surgical costs have hindered its widespread adoption. This study, from the perspective of the healthcare system, constructs a partitioned survival model to systematically evaluate the cost-effectiveness of Da Vinci robotic-assisted thoracoscopic surgery (RATS) compared to video-assisted thoracoscopic surgery (VATS) in early-stage NSCLC. Aiming to provide economic evidence to health insurance payer in China and to offer insights for the development and application of innovative medical technologies under DRG payment system in China.

II. Model Instruction

A partitioned survival model was developed to assess the expected Progression-Free Survival (PFS), Overall Survival (OS), Quality-adjusted life-years (QALYs) and life-time costs between RATS compared to VATS in I-IIIa stage non-small cell lung cancer. The partitioned survival model is similar to that used in prior economic evaluations of treatments for cancers with three mutually exclusive health states: PFS, PD and Death (Delea et al. 2015).

Patients were set into a progression-free state when entering the model and received treatment until detection of progression. The proportion of patients in each health state over the course of time was estimated based on the survival distribution for PFS and OS survival. Costs and QALYs were dependent on the treatments and the expected time in each health state. Expected PFS and OS time were estimated as the area under the curve (AUC) for the PFS and OS curves, respectively. Expected PD was calculated as the difference area between the PFS and OS curves. To evaluate the long-term health and cost outcomes, we considered six parametric distributions to estimate survival projection curve, including: exponential, Weibull, log-logistic, log-normal, Gamma and Gompertz. PFS and OS data was extracted from a published literature from Peter J. Kneuertz in 2020, which reviewed Society of Thoracic Surgeons outcomes data and surveillance records of patients with stage I-IIIa NSCLC who had undergone lobectomy from 2012 to 2017 in America (Kneuertz et al. 2020). The model time horizon was set to 10 years.

III. Costs and Utility Estimates

Model inputs in terms of costs were generated basted on medical data of Tianjin Medical University Cancer Institute and Hospital. Our hospital performs more than 3,000 lung cancer operations per year, including over 500 Da Vinci robotic lung cancer operation. The patients were mainly from Heilongjiang, Jilin, Liaoning, Inner Mongolia, Hebei, Shandong, Tianjin and other northern regions of China, which could represent the population of lung cancer patients in northern China.

At present, no data has published about the utility of QOL after RATS for pulmonary resection. Basing on the publish literature, we assumed the PFS and PD utility for RATS was similar to that for VATS (Jin et al. 2022; Jin et al. 2023). Bendixen M conducted a randomized clinical trial (RCT) to investigate the QOL after lobectomy under VATS or open thoracotomy (OT) for patients with NSCLC. The utility of VATS reported by the RCT was recognized as the utility for RATS which PFS utility was 0.815 and PD was 0.473 (Bendixen et al. 2016).

IV. Model Outcomes

The primary outcomes were total medical costs, QALYs, PFS, OS and incremental cost-effectiveness ratios (ICER).

V. Sensitivity Analyses

Sensitivity analyses were conducted to evaluate the uncertainty and robustness of the model. Deterministic sensitivity analyses (DSA) were estimated to assess the impact of key parameters on model outputs. Probabilistic sensitivity analyses (PSA) were performed with 1000 iterations of Monte Carlo simulations. All parameters were varied with a defined statistical distribution simultaneously. Gamma distribution was used for all input costs, and a beta distribution was adopted for utility and discount rate. The results of DSA and PSA were represented as a tornado diagram and cost-effectiveness acceptability curves (CEAC), respectively.

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Technology, Skills, and Performance: The Case of Robots in Surgery

By Elena Ashtari Tafti*

Disparities in access and quality of services concern regulators and policy makers. This is particularly true in healthcare, where substantial effort has been devoted to studying why differences in patient outcomes across areas and providers persist, even after controlling for patient risk (Skinner 2011). Providers' use of alternative treatments may explain part of this phenomenon (Tsugawa et al. 2017; Birkmeyer et al. 2013). Health outcomes appear nonetheless to be only marginally affected by it (Molitor 2018). In fact, heterogeneity in healthcare providers' skills may be at the root of this variation (Chandra and Staiger 2020; Hull 2018; Chandra and Staiger 2007).

In this paper, I investigate the potential of robots to reduce variation in patient outcomes. Across and within occupations, individuals differ substantially in their level of skills, and healthcare providers, such as surgeons and doctors, are no different (Chan et al. 2022; Currie and MacLeod 2017; Kolstad 2013). Differences in providers' skills generate inequality and can exacerbate systematic disparities in access (Finkelstein et al. 2016; Chandra and Skinner 2003; Deaton 2003). I show that, in England, the diffusion of robots coincided with an improvement in average surgical performance and convergence in outcomes between high and lower-skilled surgeons. I exploit quasi-random variation in the geographic allocation of robots to study whether this is attributable to adopting robotic surgery. Using administrative data on prostate cancer patients, the most common type of cancer in men in the United Kingdom (UK), I show that robots played a fundamental role in this process.

Part of my contribution is to identify the impact of this technology in the presence of both heterogeneous treatment effects and a selection problem. To this day, medical evidence that robotic surgery improves patient outcomes, relative to the more invasive alternative, has been at best inconclusive (Coughlin et al. 2018; Yaxley et al. 2016; Robertson et al. 2013; Bolla et al. 2012). Existing studies are based on small and selected samples (Neuner et al. 2012) and are not designed to identify causal effects (Ho et al. 2013). If the potential of robotic surgery to improve performance depends on surgical skills, small sample studies will reflect only part of the picture. Moreover, suppose the uptake of this technology is also heterogeneous across the skills distribution. In that case, any naive correlation will speak more to the characteristics of the adopters rather than

* Ludwig Maximilian University of Munich (email: elena.ashtari@econ.lmu.de).

the technology itself. Importantly, when treatment effects are heterogeneous, surgeons and patients may choose the robot based on their specific technological gains (Björklund and Moffitt, 1987). Regression-adjusted comparisons between robotic and traditional surgery would, in this case, provide misleading estimates if adoption is informed by unobserved factors that influence selection.

To identify causal effects, I use an approach introduced by Björklund and Moffitt (1987) and generalized by Heckman and Vytlacil (2005) that concentrates on the marginal treatment effect (MTE). In this context, the MTE is the average effect of robots on the outcome of individuals at a particular margin of indifference between robotic and traditional surgery. With this approach, I identify the causal effects of robots on patient outcomes and how these depend on surgical skills. I focus on two patient outcomes: the speed of recovery (i.e., postoperative length of stay) and the occurrence of adverse events from surgery (i.e., postoperative morbidity). These are two dimensions of surgical performance that matter to physicians, patients, and policymakers (Lotan 2012), and robotic surgery should have a measurable effect on them because it increases precision and requires smaller incisions (Higgins et al. 2017; Coelho et al. 2010; Lowrance et al. 2010; Nelson et al. 2007). I measure skills by using a single risk-adjusted indicator of surgeons' patient outcomes. Because I expect the robot to impact surgeons' performance, I estimate this indicator using data from the years preceding the national introduction of this technology. In fact, the indicator is measured when all operations were carried out without technological aid and is not affected by the surgeons' adoption behavior.

Identification of causal effects in the MTE framework requires, in most cases, no stronger assumptions than standard instrumental variable methods but poses a more substantial burden on the instrument (Cornelissen et al. 2016). Indeed, this method requires at least one instrumental variable to be continuous. I exploit the staggered adoption of robots over time to construct two instruments that arguably satisfy the conditions for identification.

I find that robotic surgery improves surgeons' performance. The robot reduces postoperative length of stay and morbidity across patients. However, my analysis shows that these effects are highly heterogeneous, and technological gains significantly depend on the surgeon's skills. High-skilled surgeons benefit the least from the technology, while lower-skilled surgeons gain the most from it. This result suggests that the robot exhibits decreasing returns in surgeon skills, which means that it complements lower- skilled surgeons more strongly than higher-skilled ones. With traditional surgery, the patients of highly skilled surgeons are four percentage points less likely to experience an adverse event than those of lower-skilled surgeons. However, with the robot, they are around one percentage point less likely to experience these events. A similar pattern emerges for the length of stay. As differences in patient outcomes between highly and less skilled surgeons shrink, my analysis suggests that the robot may potentially reduce variation in patient outcomes. That said, I uncover a strong pattern of negative selection. High-skilled surgeons use the technology more intensively, while lower-skilled ones use it less despite their higher returns. Heterogeneous actual or perceived costs to adopt the technology may explain this result (Suri 2011).

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机器人对比传统腹腔镜辅助的直肠低位前切除术治疗中低位直肠癌的卫生技术评估

武子婷 蔡泽荣 石茵 郁雨丹 潘聿航 胡雪峰 刘国恩 吕筠妮*

摘　　要　结直肠癌是我国最常见的消化道恶性肿瘤之一，直肠低位前切除术是目前开展最广、应用较多的保肛术式。关于机器人手术与传统手术在直肠癌中的效果对比，研究结论尚不一致。本研究拟对比机器人辅助与传统腹腔镜/开腹手术在接受直肠低位前切除术的中低位直肠癌患者中的成本效用。本研究拟建立一个全国多中心的观察性前瞻性队列，在接受根治性低位直肠前切除术的直肠癌患者中，评估机器人辅助手术与传统腹腔镜/开腹手术的临床疗效和健康结局的差别，并进一步评估研究观察周期内的直接医疗成本、直接非医疗成本和间接成本等多方面经济成本，从全社会的角度对比观察不同手术类型的成本效用。

一、背景

机器人辅助手术（Robot Assisted Surgery，RAS）是临床外科学发展的重要里程碑，手术机器人的发展赋予了外科手术新的概念。相比于传统的开腹手术，腹腔镜手术和机器人手术均具有对人体创伤小、术后恢复快等优点；相比于腹腔镜手术，机器人手术具有手术视野清晰、机械臂灵活、滤抖、有利于精细操作与神经功能保护等优点，但机器人手术成本比起其他两种术式高。结直肠癌是我国最常见的消化道恶性肿瘤之一，直肠低位前切除术是目前开展最广、应用较多的保肛术式。机器人在直肠低位前切除术中应用广，比起腹腔镜手术，可能具有更好的肿瘤学切除效果，并且创伤小、恢复快。

由于机器人手术耗费比传统手术高，因此有必要对机器人直肠癌手术进行卫生经济学评价，进一步明确其价值。现有研究多集中在模型分析和小规模临床数据，缺乏长期生命质量关注及基于中国人群的成本效用分析。鉴于此，本研究拟建立全国多中心、前瞻性的真实世界队列观察性研究，从全社会角度评估机器人手术与腹

* 武子婷，北京大学全球健康发展研究院；蔡泽荣，中山大学附属第六医院结直肠外科，广东省胃肠病研究所，广东省结直肠及盆底疾病重点实验室；石茵，中南大学湘雅医院药学部，中南大学湘雅医院老年疾病国家临床研究中心；郁雨丹，北京大学全球健康发展研究院；潘聿航，北京大学全球健康发展研究院；胡雪峰，北京大学全球健康发展研究院；刘国恩，北京大学全球健康发展研究院；吕筠妮(通信作者)，北京大学全球健康发展研究院(E-mail: blyu@pku.edu.cn)。

腔镜/开腹手术相比在中低位直肠癌患者中的成本效用比。

二、研究方法

本研究为全国多中心队列研究，研究拟纳入12-16个中心，随访3年。本研究的受试人群是接受根治性低位前切除手术的直肠癌患者，手术方式为手术机器人或传统腹腔镜或开腹。以3年无病生存（Disease-free survival, DFS）为主要结局计算样本量，计划入组1200例受试者，其中机器人手术组和腹腔镜手术组受试者各540例，开腹手术组受试者120例。研究入选标准为计划施行直肠低位前切除术、术前确诊为中低位直肠腺癌（经盆腔MRI测量肿瘤下缘距离肛缘≤10cm）、术前分期cT1-T3 N0-1，或新辅助治疗后ycT1-T3 Nx，无远处转移M0、美国麻醉学会评分（ASA评分）≤3、年龄18-75岁、术前患者心肺、肝肾功能良好，可耐受机器人或腹腔镜、开腹手术且已加入城镇职工医疗保险或城乡居民医疗保险。

排除标准为直肠病变为良性或非腺癌、直肠癌病灶无法施行根治性手术切除或需施行联合器官切除的患者、多源发性结直肠癌、合并家族性腺瘤性息肉病或炎症性肠病患者、过去5年内曾患者有其他系统的恶性肿瘤或研究者认为不适宜参加研究的疾病、既往曾接受研究者认为的可能影响手术操作的盆腔手术史、存在远处器官组织转移（M1）、计划施行侧方淋巴结清扫或非一期保肛术式（如经腹会阴联合直肠切除Miles术、直肠切除＋近端结肠单腔造口Hartmann术）或计划施行经肛直肠全系膜切除术（TaTME）或经自然腔道取出标本手术（NOSES）。

研究将观察患者的经济指标（包括直接医疗成本、非医疗成本和间接成本）、临床指标（包括围手术期安全性指标、围手术期并发症和肿瘤学疗效）和生命质量相关指标（术前焦虑和生命质量）。直接医疗成本将包括患者用于诊断、治疗和预防疾病而产生的医疗卫生资源的成本，包括手术费、药费、检查费等。直接非医疗成本将包括治疗疾病额外增加的交通、食宿等费用。间接成本将包括因病造成患者和家庭成员的休学、停工或工资损失。围手术期安全性指标包括围术中出血量、是否转为开腹手术、术后首次排气时间、术后30天非计划再次入院、术后30天内非计划二次手术、术后30天内死亡等。此外，记录手术切口数量、位置和长度以及是否出现伤口感染、吻合口漏、排尿功能障碍等。研究将使用EQ-5D-5L测量患者的生活质量，使用术前焦虑量表评估患者焦虑程度。研究将同时收集患者的人口学特征、社会经济学指标（如教育、职业）等基线特征。

入组后，研究拟随访患者3年，分别在术后、术后1月、3月、6月、9月、12月、18月、24月、30月和36月采集以上信息，收集的方法主要使用医院现有数据获取

和问卷调查方式。

本研究将采用增量成本-效果分析（Incremental Cost-Effectiveness Analysis, ICEA）和增量成本-效用分析（Incremental Cost-Utility Analysis, ICUA）分析方法，通过比较机器人组和腔镜组、机器人组和开腹手术组的增量成本效果比 (incremental cost-effectiveness ratio, ICER) 和增量成本-效用比（Incremental Cost-Utility ratio, ICUR），来评价机器人手术的经济性和价值。

引入手术机器人对手术死亡率的影响

陈尔默*

摘　要　这项回顾性研究旨在分析机器人手术对死亡率的影响，调查医疗系统引入医疗机器人后死亡率的变化情况。这是医疗事故研究项目的一部分。分析使用了两个数据源，一个是市场上占主导地位的医疗机器人供应商的服务记录，另一个是一家信息技术供应商提供的覆盖中国数千家医院的统计结果数据。结果显示，医疗机器人能显著降低手术死亡率，这可能意味着医疗机器人能减少医疗事故。我们还将对此进行进一步研究。

一、背景介绍

先前的研究并未显示引入医疗机器人对手术有明显的好处（Borden et al.，2007; Alemzadeh et al.，2016）。而在现实世界中，医疗机器人确有越来越受欢迎的趋势。因此，还需要挖掘该趋势更多的驱动因素。在既往的队列研究中，由于样本太少，无法得出关于期望之外的度量可靠的结果，如风险和不确定性。这使我们必须开展以回顾的方式使用更大的数据集的研究。

在本文中，我们研究引入医疗机器人对死亡率变化的影响。结果表明，医疗机器人可显著降低手术死亡率。本研究是手术机器人对医疗事故和医疗错误影响研究的一个部分。

二、数据

本文的研究基于一家在市场上占据主导地位的医疗机器人供应商在中国大陆的服务记录，记录了每个病例的医院名称、手术日期和手术类别。同时，我们也使用一家信息技术提供商的统计报告。该报告是一份基于内部数据的统计报告，样本涵盖 2007-2022 日历年的中国大陆 6252 家医院。每个医院每个月的样本数、死亡率、平均费用、费用差异和住院天数，以及每个手术或科室的类别都有报告。此外，报告还提供了医院的地点、级别和等级。

两个数据源可以通过医院和日期进行匹配。分析覆盖 6252 家医院，其中 97 家有医学机器人的手术记录，覆盖了手术记录的 28328/314152=9%。经过数据清洗，

* 北京大学数学科学学院/全球健康发展研究。
通信地址：北京市海淀区颐和园路五号，100871；E-mail: chenermo@stu.pku.edu.cn。

4231 家医院，30936 个医院 × 季度进入统计分析。

三、死亡率建模

本章的回归模型使用

$$DeathRate_{i,t} \sim Robot_{i,t} + X_i + I_t, \quad \omega = SampleSize_{i,t}, \qquad (1)$$

其中 $Robot_{i,t}$ 是机器人使用的程度，采用例数 (Num_of_Robot) 和例数占比 (Robot_Rate) 两种口径。这是因为统计记录数据是根据样本得出的，而不是完整的记录，因此例数占比的评估不够准确。但例数占比是对效果进行显著性检验所必需的。因此，在分析过程中要同时考虑这两个因素。

考虑两种固定效应。一种是直接使用医院的唯 ID，这种方法比较简单，但受限于统计结果数据中的一些缺失结果。另一种是使用医院所在的省、医院等级和医院级别来代替，这可能会丢失一些信息，但结果会更加稳健。我们对两种方法均加以使用。

四、模型结果

基于例数的模型结果如下表所示

基于例数的模型结果				
例数	1.65E-06	1.12E-06	-6.19E-06	-2.12E-06
例数的显著性	0.0838	0.2436	0.0000	0.0094
固定效应：时间		Yes	Yes	Yes
固定效应：医院				Yes
固定效应：科室				
固定效应：省份			YES	
固定效应：医院等级			YES	
固定效应：医院级别			YES	
样本点数	30,936	30,936	30,936	30,936
F统计量	2.9890	5.1351	100.2786	17.8164
拟合优度	0.0001	0.0104	0.2454	0.7417

结果表明，在控制时间和医院的固定效应（直接和间接）的情况下，机器人手术次数与死亡率之间存在明显的负相关关系。如果不控制固定效应，尤其是医院效应，结果就会变得复杂。这是由于医院在引进机器人时存在选择偏差造成的，这种偏差很常见，因为机器人的手术是非常昂贵的。

五、结论

结果表明，医疗机器人可以大大降低手术死亡率。这可能意味着医疗机器人可以减少医疗失误。我们将进一步研究医疗机器人对平均成本、成本差异和住院天数的影响，并通过后续的研究工作展开进一步的验证。

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基于真实世界数据的机器人辅助前列腺癌根治术的临床评价研究

雍鑫 刘振华 毛宇婕 王狄佳 董强 罗冰洁 赵颖 王晓冬 陈蕾*

摘　　要　前列腺癌根治术是局限性前列腺癌的首选治疗手段之一，其中机器人辅助前列腺癌根治术（RALP）以其精确度和微创性吸引了医疗界的广泛关注。然而，对RALP的有效性、安全性及经济性的系统评估尚不充分。本回顾性研究计划通过对四川大学华西医院2017年至2021年间进行的RALP手术案例采用卫生技术评估（HTA）方法进行深入分析，涵盖手术成本、临床效果及患者安全性等方面。

随着前列腺癌的发病率持续攀升，寻找有效、安全且经济的治疗方法成为全球性的医疗挑战。前列腺癌根治术是局限性前列腺癌的首选治疗手段之一，其中机器人辅助前列腺癌根治术（RALP）以其精确度和微创性吸引了医疗界的广泛关注。然而，对 RALP 的有效性、安全性及经济性的系统评估尚不充分。本回顾性研究计划通过对四川大学华西医院 2017 年至 2021 年间进行的 RALP 手术案例采用卫生技术评估（HTA）方法进行深入分析，涵盖手术成本、临床效果及患者安全性等方面。此研究旨在为卫生行政部门和医院提供设备配置决策的有力依据，优化前列腺癌的治疗路径。目前该项目主要进展情况如下：

1. 因该研究涉及临床患者相关数据提取和分析，目前已根据医院生物医学伦理审查会要求和流程，上报研究方案、学术审查等资料，并已审核通过，于 2024 年 1 月获得四川大学华西医院生物医学伦理审查委员会批件 2024 年审（43）号，准予进行课题伦理数据研究；

2. 经与泌尿专业、经济学专业等相关专家进行课题研究指标论证，以及结合医院信息中心现有数据的情况，目前课题组正进一步优化和明确安全性、有效性和经济性指标的具体评价维度和内容，讨论达成共识如下：

（1）传统开放性手术非临床主流前列腺癌根治方式，手术量少，数据量不足，

* 雍鑫：四川大学华西医院设备物资部；刘振华：四川大学华西医院泌尿外科；毛宇婕：四川大学华西医院设备物资部；王狄佳：四川大学华西医院设备物资部；董强：四川大学华西医院泌尿外科；罗冰洁：四川大学华西医院设备物资部；赵颖：四川大学华西医院设备物资部；王晓冬：四川大学华西医院管理研究所；陈蕾（通信作者）：四川大学华西医院神经内科（E-mail: leilei_25@126.com）。

取消该分组；

（2）有效性和安全性指标方面，临床分期指标非病例必填项，数据量不足，且存在较大主观性，删除该指标；前列腺体积、术中输血率、中转开刀率、手术感染率、功能评估量表、肿瘤阳性切缘率和生化无复发生存率等指标在病例中无记录或无标准化记录，需进一步调整；穿刺活检 Gleason 评分、基础病有无、术中出血量、引流管拔出时间、手术并发症等指标病例中无完整记录，需进一步调整。同时，可增加病理、检验相关数据（如术前术后血红蛋白值）作为评价指标便于数据提取，且较能够侧面反映部分指标情况；

（3）经济性指标方面，设备运行维护成本评价意义较小，无法准确衡量成本费用，建议经济性指标整体侧重于术后相关费用（如术后护理、二次手术费用等）评价。

机器人与腹腔镜用于肝细胞癌切除的卫生经济学研究

梁霄 官海静 郑俊浩 杨辰越*

摘　　要　为探索医学机器人相比腹腔镜用于肝切除术的临床价值与医疗费用，我们回顾性收集了浙江大学附属邵逸夫医院2016年1月-2023年7月接受微创肝切除术的肝细胞癌患者的数据，分析机器人肝切除与腹腔镜肝切除术治疗肝细胞癌的成本效应。共有277例患者被纳入本研究（腹腔镜肝切除组175例，机器人肝切除组102例）。在应用倾向性评分匹配控制混杂因素后，共162例患者（两组各81例）被纳入进一步分析。结果显示，机器人肝切除组相比腹腔镜肝切除组术中出血、术后并发症较少、中转开腹率较低，手术安全性更好。机器人肝切除组具有更高的医疗费用（82885.3 vs. 58643.8￥, p＜0.001），然而，腹腔镜肝切除组除手术外的其他各项费用显著更高。另外，在高难度肝切除术中，两种术式的费用差距减小。对于肝细胞癌患者，机器人肝切除比腹腔镜肝切除具有更好的手术安全性和更高的医疗费用，然而，机器人肝切除的手术以外费用更低。另外，手术难度的提高缩小了两种术式的费用差距。

一、简介

机器人肝切除术（robotic liver resection, RLR）作为一项新技术，相比腹腔镜肝切除术（laparoscopic liver resection, LLR）可能具有更佳的手术安全性，但其手术费用往往更高。因此，使用机器人切除术治疗肝细胞性肝癌（Hepatocellular carcinoma，HCC）是否具有经济学效应，目前仍然缺乏相关证据。

二、文献回顾

当今机器人肝切除相关的卫生经济学研究在在国内外报道较少。2022 年 1 篇纳入了 4 篇相关文献的 meta 分析显示，RLR（20,205.92 美元）的成本远远高于 LLR（15,789.75 美元）。费用成为是制约 RLR 开展的重要因素（Ciria et al.，2022）。然而，随着现代医学的发展，手术不仅是为了治愈，也是为了提高生活质量。2020

* 梁霄（通信作者），浙江大学医学院附属邵逸夫医院（E-mail: 3190104362@zju.edu.cn）；官海静，首都医科大学附属北京天坛医院；郑俊浩，浙江大学医学院附属邵逸夫医院；杨辰越，浙江大学医学院附属邵逸夫医院。

年 Mejia 等报道了 214 例肝切除患者，指出与 LLR 相比，RLR 尽管费用更高，但患者住院时间更短，对于小范围肝切除患者是更好的选择（Mejia et al.，2020）。然而，2016 年我国学者根据机器人和腹腔镜肝左外叶切除手术的 39 例患者资料指出，对于肝左外叶切除，RLR 比 LLR 手术费用更昂贵，但在疗效和安全上差异无统计学意义（Yin et al.，2016）。因此，RLR 是否能改善生活质量并具有成本效益仍然是一个争论。

2023 年的国际机器人肝切除专家指南指出，相较于 LLR，RLR 在肝脏相关疾病中具有独特的治疗价值，其成本效用值得未来继续研究（Liu et al.，2023）。在泌尿外科、大肠外科等学科中，已有研究认为机器人手术具有成本效益，或者指出有利于提高机器人的应用率所需降低的费用（Simianu et al.，2020；Song et al.，2022）。

三、研究方法

开展真实世界研究，回顾性收集浙江大学附属邵逸夫医院 2016 年 1 月 -2023 年 7 月诊断为 HCC 的住院患者，根据患者的手术方式分为 RLR 组与 LLR 组，在描述性分析的基础上，通过倾向性评分匹配控制混杂因素，探索不同治疗方式对于治疗结局和医疗费用的净效益，并进行经济学评价。开展亚组分析，探索研究结果的稳健性。

正态分布的连续变量描述为平均值 ± 标准差，偏态分布的连续性变量描述为中位数（四分位距），分类变量描述为频率和百分比。将年龄、BMI、AFP、INR、ALB、AST、TBIL、Child 分级、血管浸润、手术难度、ASA 分级作为协变量纳入模型进行拟合，计算倾向性评分，进行最邻近法匹配。PSM 采用 SPSS 25.0 版本进行分析。将患者按照 IWATE 手术难度分级分为“低难度”“中等难度”“高难度”“专家难度”4 个亚组，进行亚组分析。

四、结果

经纳入、排除标准筛选后，共有 277 例患者被纳入本研究，根据手术方式分为 LLR 组（175 例）和 RLR 组（102 例）。在倾向性评分之前，LLR 组的术中出血量（p=0.000）、术中输血率 (p=0.045)、术后并发症发生率（p=0.003）、术中转开放率（p=0.001）、住院时间（p=0.001）、术后住院时间（p=0.001）显著高于 RLR 组，LLR 组的住院总费用（p=0.000）、自付费用（p=0.000）、手术费用（，p=0.000）显著低于 RLR 组，然而药物费用（p=0.000）、检查费用（p=0.010）、护理费用（p=0.001）、耗材费用（p=0.000）显著高于 RLR 组。经过倾向性评分匹配平衡基线指标后，162

例患者（LLR 组与 RLR 组各 81 例）纳入进一步分析。结果显示，LLR 组的术中出血量（p=0.002）、术后并发症发生率（p=0.043）、住院时间（p=0.005）、术后住院时间（p=0.000）显著高于 RLR 组，LLR 组的住院总费用（p=0.000）、自付费用（p=0.000）、手术费用（p=0.000）、其他费用（p=0.004）显著低于 RLR 组，药物费用（p=0.000）、检查费用（p=0.010）、护理费用（p=0.001）、耗材费用（p=0.000）显著高于 RLR 组。（见表 1）

以 IWATE 手术难度分级为协变量进行亚组分析，结果显示，在“低难度”“中等难度”“高难度”3 个亚组内，LLR 组的住院总费用显著高于 RLR 组（低难度：p=0.000；中等难度： p=0.003；高难度：p=0.001），然而，在“专家难度”组内，LLR 组与 RLR 组的住院总费用没有显著性差异（p=0.325）。另外，可以观察到随着手术难度的升高，RLR 组与 LLR 组住院总费用的差距在缩小。

表1　PSM前后LLR组与RLR组结局指标

Outcome	Before PSM (n=277)			After PSM (n=162)		
	LLR (n = 175)	RLR (n = 102)	p value	LLR (n=81)	RLR (n=81)	p value
Optime (IQR), min	160 (115)	166 (106)	0.263	180(130)	160 (113)	0.134
Status_of_surgical_margin, n(%)			0.494			1
R0	166 (98.2)	98 (96.1)		79(98.8)	79(97.5)	
R1_or_R2	3(1.8)	4(3.9)		1(1.3)	2(2.5)	
Hemorrhage_during_operation (IQR), mL	100.0 (350.0)	50.0 (63.0)	<0.001	100.0 (225.0)	50.0(75.0)	0.002
Intraoperative_transfusion, n(%)	33(18.9)	10(9.8)	0.045	12(14.8)	8(9.9)	0.339
Complication, n(%)	35(20.0)	7(6.9)	0.003	16(19.8)	7(8.6)	0.043
ClavienDindo, n(%)			0.006			0.062
No	140(80.0)	95(93.1)		65(80.2)	74(91.4)	
I_or_II	25(14.3)	6(5.9)		10(12.3)	6(7.4)	
III_or_IV_or_V	10(5.7)	1(1.0)		6(7.4)	1(1.2)	
Open_conversion, n(%)	20(11.5)	0(0.0)	0.001	5(6.2)	0(0.0)	0.069

Re_operation, n(%)	0(0.0)	0(0.0)	/	0(0.0)	0(0.0)	/
Mortality_in_hos, n(%)	0(0.0)	0(0.0)	/	0(0.0)	0(0.0)	/
PostopStay (IQR), day	6.0(3.0)	5.0(3.0)	0.001	6.0(3.0)	5.0(3.0)	0.005
Re_admission_30days, n(%)	3(1.7)	1(1.0)	1	2(2.5)	1(1.2)	1
LOS (IQR), day	13.0(6.0)	9.5(6.0)	<0.001	12.0 (6.0)	10.0(4.0)	<0.001
Hospitalization_cost (IQR), ¥	57150.9 (31989.2)	81432.5 (16289.2)	<0.001	58643.8 (30728.6)	82885.3 (14883.9)	<0.001
Out_of_pocket_payment (IQR), ¥	16875.0 (13102.7)	50333.4 (11358.2)	<0.001	15972.7 (14057.0)	50706.2 (10843.8)	<0.001
Drug_cost (IQR), ¥	15879.4 (12239.8)	9955.6 (6319.6)	<0.001	16517.6 (12034.57)	9975.0 (6255.6)	<0.001
Surgery_cost (IQR), ¥	6916.0 (1532.3)	43424.9 (1089.4)	<0.001	6616.0 (1316.4)	43424.9 (1240.4)	<0.001
Examine_cost (IQR), ¥	1260.0 (1223.0)	1160.0 (1079.8)	0.01	1365.0 (1265.0)	1115.0 (943.0)	0.001
Nursing_cost (IQR), ¥	1164.0 (642.0)	989.6 (507.25)	0.004	1174.0 (722.5)	988.6 (475.2)	0.012
Material_cost (IQR), ¥	21113.4 (15925.4)	12094.4 (7195.0)	<0.001	21565.4 (16942.8)	12069.4 (8195.4)	<0.001
Other_cost (IQR), ¥	386.0 (540.0)	486.5 (605.2)	0.054	341.0 (401.4)	535.0 (586.5)	0.004

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基于真实世界数据的机器人辅助髋膝关节置换术临床效能和卫生经济学评价

吕蓓妮 宋洋 周一新*

摘　　要　我国髋膝关节疾病负担重，其中人工关节置换是治疗终末期髋膝关节炎最有效的方法。相比于传统的手术方式，机器人辅助髋膝关节置换具有定位精准度高、一致性强、术后疼痛减少以及功能恢复早等优点，有望改善患者预后。但机器人辅助髋膝关节医疗费用较传统手术高，是否具体经济性需要进行系统的卫生经济学评价。本研究依托患者个体水平的数据，将纳入接受全膝关节置换和全髋关节置换的患者，结合医疗电子病历数据和主动随访，明确机器人辅助手术与传统手术相比，对患者的临床结局、生活质量和医疗支出的影响，使用成果效果分析明确机器人辅助髋膝关节置换的经济性。

一、背景

随着我国人口老龄化程度不断加剧，髋膝关节炎疾病负担也在不断上升，截至2019年底，我国约1.2亿人口患有髋膝关节炎（Long et al.，2020）。人工关节置换是治疗终末期髋膝关节炎最有效的方法（Kim et al.，2020）。传统的髋膝关节置换术面临着手术精准性不足、缺少数字化智能化工具、翻修失败率高等问题。而机器人辅助髋膝关节置换凭借其定位精准度和一致性高、术后疼痛减少以及功能恢复早等优点而受到广泛关注（Yang et al.，2024；Subramanian et al.，2019）。早期的研究表明，与传统手术相比，机器人辅助关节置换术具有准确辅助截骨、个体化置入假体、更好地保护膝关节周围软组织、减少镇痛药物使用、缩短住院时间等优势，但也存在手术耗时延长等不足 (Shao et al.，2023；Subramanian et al.，2019；Yang et al.，2024)。尽管机器人辅助关节置换有望改善患者预后，但其医疗费用远高于传统手术，这对于平衡有限的医疗资源与提升患者健康水平构成了挑战。骨科手术机器人在基础医疗保险方面的政策正在逐渐完善，针对机器人辅助关节置换，目前国内缺乏系统的经济性评价，这制约了医保支付等关键政策的制定和调整。利用接受髋膝关节转换的真实世界患者数据，研究将对比机器人辅助手术和非机器人手术髋、膝关节转换的临

* 吕蓓妮（通信作者），北京大学全球健康发展研究院（E-mail: blyu@pku.edu.cn）；宋洋，首都医科大学附属北京积水潭医院；周一新，首都医科大学附属北京积水潭医院。

床效果、生活质量和成本，致力于明确机器人辅助髋膝关节置换的成本效果。

二、方法

研究将采用回顾性队列研究，纳入2020.8-2023.12期间因骨关节炎或关节畸形于就诊于积水潭医院矫形骨科，接受机器人辅助或传统全膝关节置换/全髋关节置换术、ASA评分I-II级、21-80岁的患者。研究排除妊娠期女性患者、膝关节翻修患者、伴有严重的屈曲畸形（＞20°）及严重内外翻畸形（＞20°）、类风湿性关节炎、感染性关节炎的患者。

患者的人口学特征（如年龄、性别）、手术适应症、并发症（包括高血压、糖尿病、冠心病、骨质疏松）、手术相关信息（包括手术部位、时长、术中出血量等）、医疗支出（总住院费用、手术费用、诊疗费、检查费等）将依据医疗电子病历确认。患者放射学评估指标（如髋-膝-踝角、股骨远端外侧角和胫骨近侧内侧角）将请骨科医生阅片评估。研究将通过电话随访明确患者是否出现假体翻修、假体松动等事件。同时，研究将采用EQ-5D-5L测量患者的生活质量，使用WOMAC评分评估关节和患者满意度，以上两个评分将通过电话随访完成。

在数据分析上，研究将针对全膝关节置换和全髋关节置换分别展开分析。研究将首先对机器人辅助和传统髋膝关节置换术的成本和效果进行描述性分析，比较两组患者在临床指标、生命质量和各项费用等方面的差异。研究将使用生存分析评估不同术式对关节翻修率的影响，使用两步模型评估不同术式对医疗费用的影响，使用线性回归分析不同术式对关节功能和满意度的影响。为了平衡两组患者可能的差异，研究将采用倾向性评分，结合逆概率加权法，减少患者基线差异对结果的影响。研究将进一步计算机器人辅助髋膝关节置换组和传统手术组的增量成本效果比（incremental cost-effectiveness ratio, ICER），判断机器人辅助髋膝关节手术的经济性。

三、初步结果

通过前期数据清理，研究纳入机器人辅助全膝关节置换手术患者250例，患者平均年龄为66.9(7.5)岁。研究已1：1匹配年龄、性别纳入接受非机器人辅助全膝关节置换手术患者，目前正开展数据清理和患者随访中。研究将进一步纳入全髋关节置换手术的患者。

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手术机器人卫生技术使用现况与影响因素分析研究动态：使用现况与主观态度调查设计

陈婷 敖露 潘聿航 周楚帆 潘杰*

摘　要　手术机器人的使用在不同的供方（机构、医生）、术式和患者特征下呈现出的成本效益差异明显。对技术现况分布与规律成因的掌握是HTA和相关卫生经济研究设计的基础。本课题以“现况描述-分布差异-差异剖析”为主要的结构思路。目前，采用时空描述方法展示了我国达芬奇手术机器人的部分使用情况和分布差异；基于文献回顾和专家咨询初步设计了主观调查方案，构建了基于决策者、外科医生和患者的主观态度理论基础与问卷提纲，以待后续的调研与分析。

一、背景

创新被视为进步的必要条件。上个世纪中下叶以来，医疗卫生领域的技术创新和进步发展迅猛，为卫生体系的能力建设和提升提供了长足的动力基础（Gelijns，1990）。然而，技术在卫生医疗领域中的应用仍然不足，以美国医疗保健的数据为例，与信息、金融保险等其它行业相比，医疗卫生的行业增长率高于整体经济增长的平均水平，但其劳动生产增长率却位居倒数，原因之一便是卫生技术的使用滞后（Sahni et al.，2017）。

手术机器人作为新兴卫生技术的代表虽扩散速度快、范围广、市场规模大（Peters et al.，2018），但其在医疗保健中的应用也面临着不少障碍（Randell et al.，2019; Szabó et al.，2024），导致其技术扩散分布不均衡、效益发挥不充分（Miraldo et al.,2019）。除开技术本身的限制，技术采用或使用者的人口社会、经济和心理等因素被认为是影响手术机器人是否被采用、能否充分发挥其临床、经济和社会效益的重要制约 (Randell et al.,2019)，也导致技术的成本效益在不同术式和研究对象间千差万别（Abrishami et al.，2020）。

* 陈婷，四川大学华西公共卫生学院/四川大学华西第四医院HEOA Group（E-mail：chenting_723@163.com）；敖露，四川大学华西公共卫生学院/四川大学华西第四医院HEOA Group（E-mail：2352480696@qq.com）；潘聿航，北京大学全球健康发展研究院（E-mail：yhpan@pku.edu.cn）；周楚帆，四川大学华西公共卫生学院/四川大学华西第四医院HEOA Group（E-mail: 2023224040041@stu.scu.edu.cn）；潘杰（通信作者）：四川大学华西公共卫生学院/四川大学华西第四医院HEOA Group（E-mail：panjie.jay@scu.edu.cn）。

我国尚处于手术机器人应用早期，如何有效管理和推进手术机器人的发展是一个重要议题。目前，我国手术机器人的应用现况、分布特征和人群公平性还尚未可知，并严重缺乏实证证据。对手术机器人的分布现况与差异特征的掌握是HTA和相关卫生经济研究设计的基础。同时，剖析不同利益相关者对手术机器人的主观态度和接受度可反映“真实世界”视角下的市场规律与成因，有助于提高医疗程序的效率和公平性，为“以人为中心”的手术机器人发展提供证据。本课题拟基于医疗机构决策者、医生和患者三方视角，从客观和主观两个维度了解我国手术机器人使用的现况和分布差异，考虑地区和人群层面的公平性，并剖析影响各利益相关方应用技术的宏观、中观和微观影响因素，为相关医疗卫生市场管理和技术推进政策提供实证基础与建议。

二、方法

目前，本研究采用时空描述统计方法展示了我国达芬奇手术机器人的部分使用情况和分布差异，使用的数据主要为2007-2022年我国达芬奇手术机器人技术使用记录数据；以省为单位探索新兴技术代表——达芬奇手术机器人技术的人群公平性；基于文献回顾和专家咨询初步设计了主观调查方案，构建了基于决策者、外科医生和患者的主观态度理论基础与问卷提纲，以待后续的调研与进一步分析。

三、结果

（一）我国达芬奇手术机器人的使用现况与分布

自2007年我国首次引进达芬奇手术机器人以来，至2022年第二季度末，我国共引进达芬奇手术机器人269台，使用达芬奇手术机器人进行手术314,152例，无论是设备量还是使用量逐年呈上升趋势，特别是2014年中后期开始，技术使用量上升速度明显提升并呈现指数增长趋势（排除2019-2020年受新冠疫情影响），见图1。

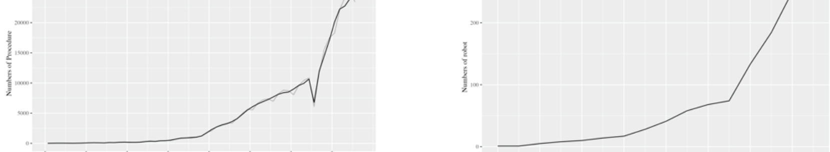

图1 2007-2022年达芬奇手术机器人引进和使用时间趋势

我国达芬奇手术机器人的使用在各省份的分布差异显著，首先应用于北京、上海和广东等经济发达地区，后逐渐向内陆欠发达地区，但直至2022年中，新疆、青海、

宁夏等省份使用量仍较少，西藏地区仍无技术的引进，整体分布趋势与人口经济特征具有相关性，见附图 1、2。

截止 2022 年第二季度，我国共 229 家机构引进达芬奇手术机器人，共 228 家医院和 1 家医学中心，其中 226 家为三甲医院（99.12%），223 家为公立医院（97.81%），219 家为科研型医院（96.05%）。在所有手术病例中，泌尿外科手术最多，占 45.58%，其次为普通外科（25.82%）、胸外科（14.23%）和妇产科（11.37%）。使用量最多的术式类型为前列腺切除术（18.49%）、肾部分切除术（13.05%）和肺切除术（10.37%），见附表 1。

（二）达芬奇手术机器人技术采用的理论框架

研究通过系统的文献证据回顾（Szabó et al.，2024; Compagni et al.，2015；Randell et al.，2019；Abrishami et al.，2014；Maynou et al.，2022；Sundaresan et al.，2023；Menchik，2020）和专家咨询构建了基于机构决策者、外科医生和患者采用达芬奇手术机器人影响因素的理论框架，其中包括相关利益方的客观条件和主观态度因素。基于此理论框架，本研究已初步构建决策者、外科医生和患者的访谈提纲及问卷。根据对技术使用的时空分布描述，并基于创新扩散理论，本研究拟选定一家“技术先行者”（2014 年之前引入手术机器人的医院），一家“技术保守者”（2014 年之后引入技术）和一家“未跟风者”（尚未引入技术的三甲医院）机构进行下一步调研。

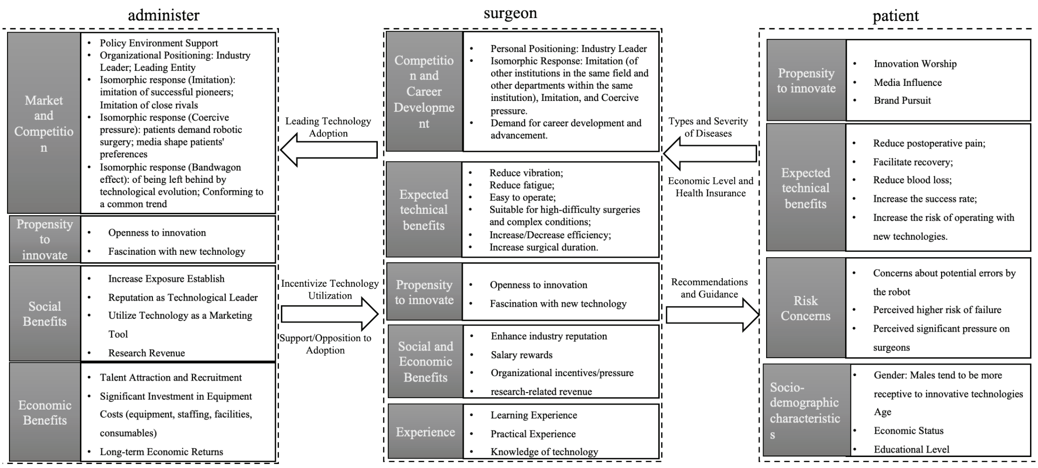

图 2 手术机器人技术采用影响因素理论框架图

四、总结与进一步计划

目前，本研究对我国达芬奇手术机器人的使用现况和分布差异进行了初步的分析，并完成系统的文献证据回顾与部分专家咨询，构建了影响因素研究的理论框架和调查方案。接下来本研究将对分布的差异性与公平性进一步剖析，结合需方患者的特征进一步探索其规律和成因，并开展实地调研收集一手数据，为我国手术机器人相关研究政策制定提供证据基础。

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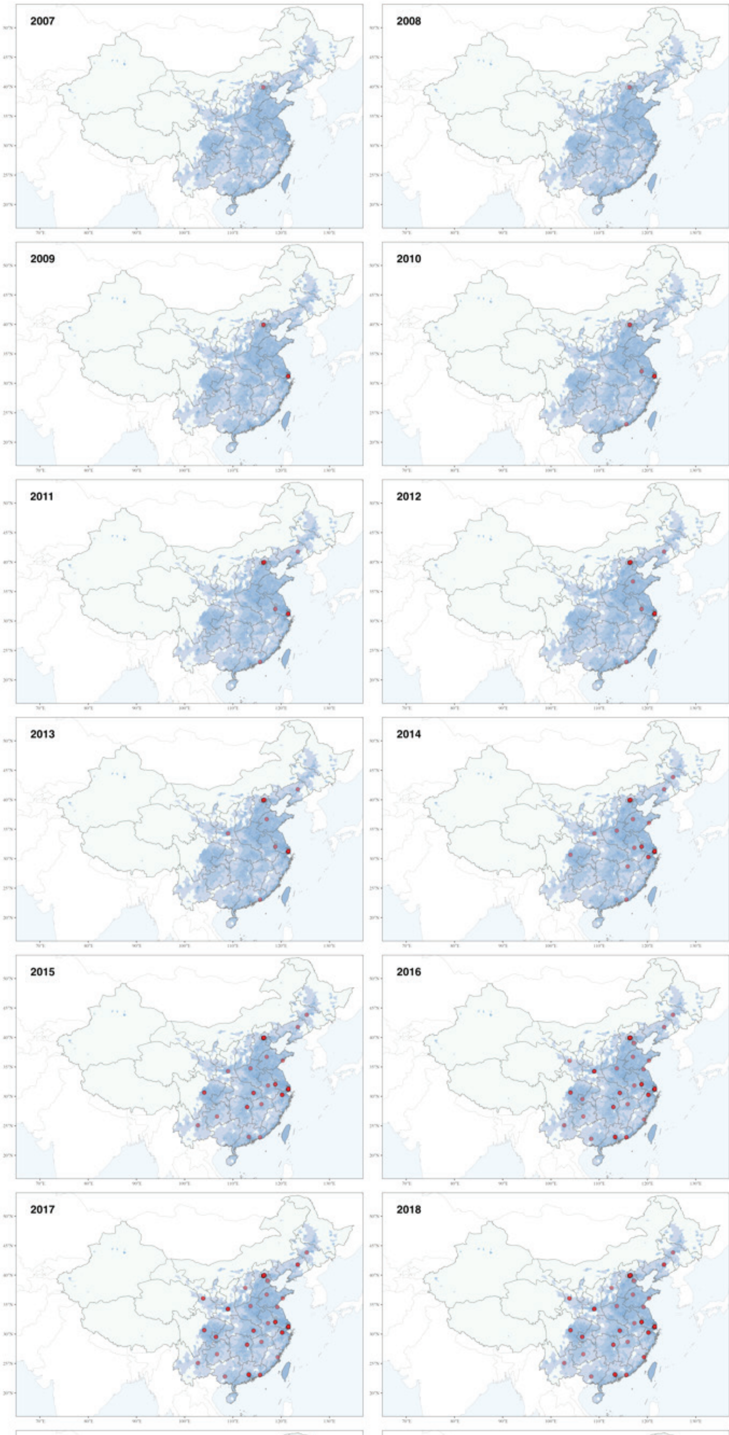
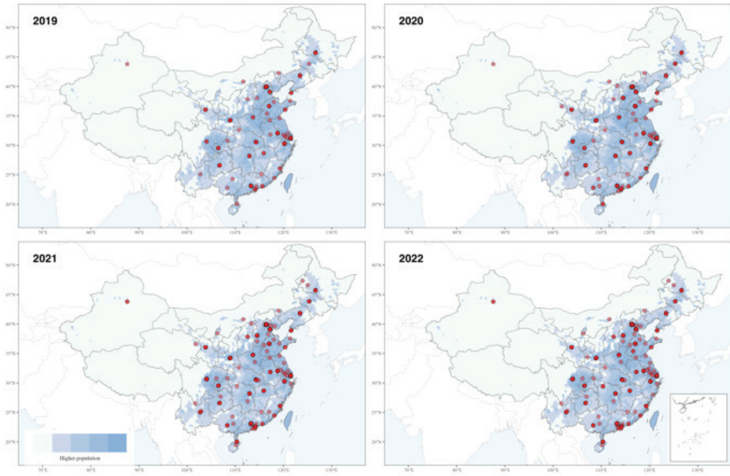
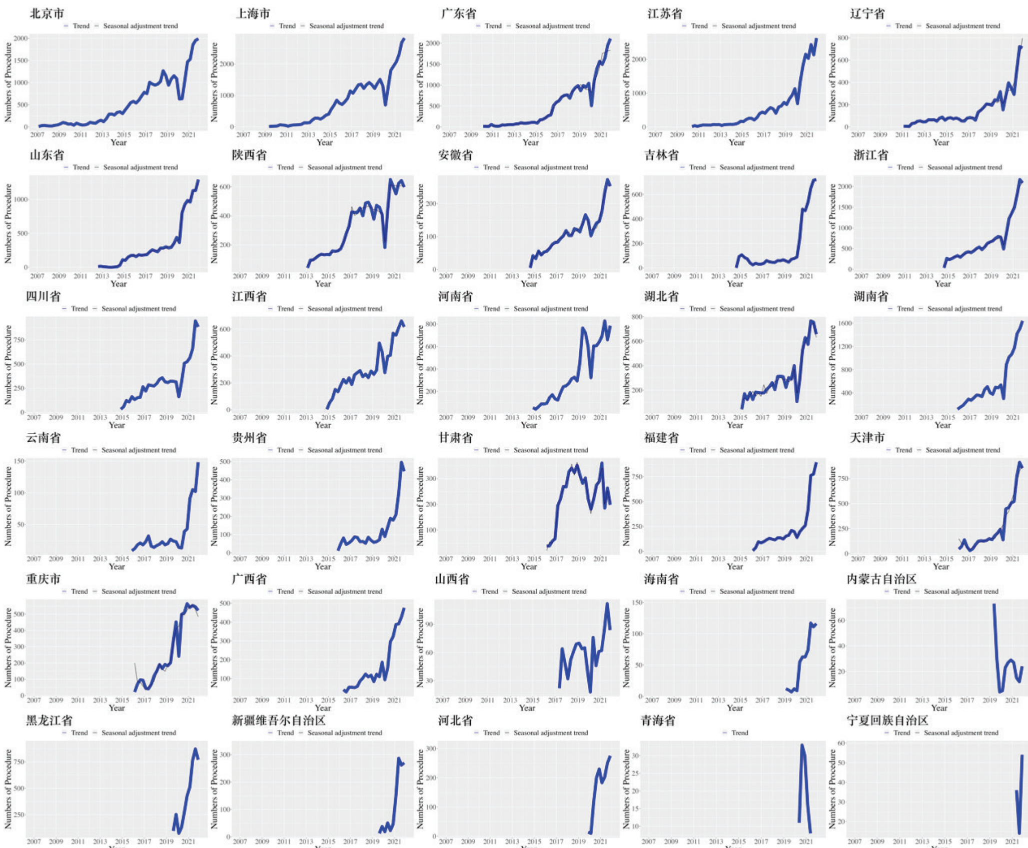
附录

附图 1 达芬奇手术机器人使用时空分布图





附图2 各省份达芬奇手术机器人使用情况分布



附表 1 术式类型手术量前十位

排序	术式		手术量
1	前列腺切除术	Prostatectomy	18.49%
2	肾部分切除	Partial Nephrectomy	13.05%
3	肺切除术	Lung Resection	10.37%
4	子宫切除术-恶性	Hysterectomy - Malignant	7.99%
5	肝胆胰切除术	HPB	7.11%
6	直肠切除术	Rectal Resection	7.03%
7	胃切除术	Gastrectomy	4.22%
8	肾切除术	Nephrectomy	4.04%
9	胆囊切除术	Cystectomy	3.85%
10	甲状腺	Thyroid	2.81%

中国医院手术机器人的引入

梁钧霆 潘聿航*

摘　　要　伴随其前所未有的经济发展和日益增长的需求，中国已成为手术机器人普及最快的国家之一。这篇文章将简要介绍中国医院，特别是医院科室里达芬奇手术系统（达芬奇外科手术系统）的技术采用情况。

伴随其前所未有的经济发展和日益增长的需求，中国已成为手术机器人普及最快的国家之一。这篇文章将简要介绍中国医院，特别是医院科室里达芬奇手术系统（达芬奇外科手术系统）的技术采用情况。截至 2022 年，直观复星被认为是最大的机器人辅助手术（Robotic Assisted Surgery，RAS）技术培训供应商，并获得 FDA 等认证。全球范围内，有超过 70 个国家近 7000 台达芬奇系统执行了超过 1000 万次微创机器人手术程序（Xue and Liu, 2022）。

2006 年，中国人民解放军总医院引入了达芬奇手术系统，是我国首家引入该系统的医院。从 2006 年至 2023 年，中国共有 284 家医院安装了达芬奇系统，约 2300 名外科医生在各种外科手术中使用该系统。这些外科医生使用达芬奇系统完成了超过 180 种手术，其中在泌尿外科手术量最高，约有 15 万次。

中国医院现有的达芬奇手术系统包括 DaVinci SP、DaVinci S、DaVinci Si 和 DaVinci Xi 四类。我们主要关注达芬奇手术系统在不同类别和不同科室中进行的第一台手术。图 1 展示了达芬奇手术系统在中国医院的普及情况。可以观察到两个显著的增长期。第一个发生在 2014 年，当时拥有达芬奇系统的医院数量几乎翻了一番。第二次增长期发生在 2019 年，拥有至少一台达芬奇手术系统的医院数量从 69 家增加到 119 家。

* 梁钧霆: 北京大学全球健康发展研究院 (E-mail: kwanting@stu.pku.edu.cn)；潘聿航（通信作者）：北京大学全球健康发展研究院（E-mail: yhpan@pku.edu.cn）。我们感谢达芬奇提供的市场数据。

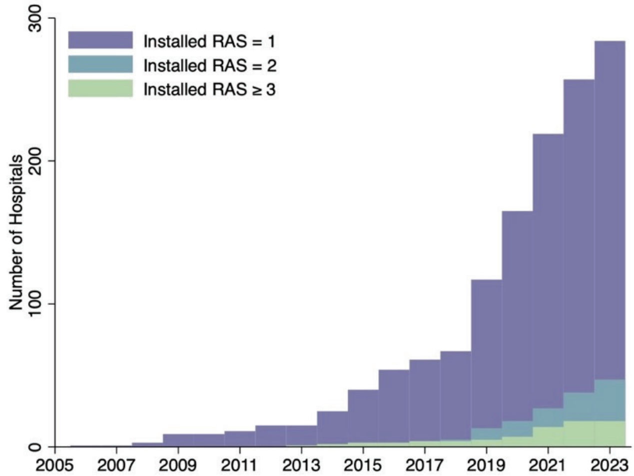


图 1 中国拥有达芬奇手术系统的医院数量

图 2 描绘了安装达芬奇手术系统和其在各个外科部门安装与首次使用之间的时间间隔。数据表明，普通外科和泌尿外科部门从系统安装到运行的时间间隔较短，可能是由于这些领域手术对达芬奇手术系统高需求和直接适用性。达芬奇手术系统可用于广泛的手术程序。在泌尿外科，它可以执行前列腺、肾脏和膀胱癌的微创手术。在普通外科领域，该系统可以在复杂的消化系统里进行胃癌和直肠癌的微创手术切除。胸外科则利用达芬奇的先进能力处理肺癌和食管癌等疾病。在妇科，达芬奇系统可以用于子宫切除，宫颈癌，卵巢癌等妇科癌症。在图 2 的分类基础上，我们的分析扩展到医院部门级别，包括小儿外科、胃结直肠外科、肝胆胰外科和甲状腺外科。

如图 3 所示，只有甲状腺外科在达芬奇系统安装与其首次操作之间有显著间隔。

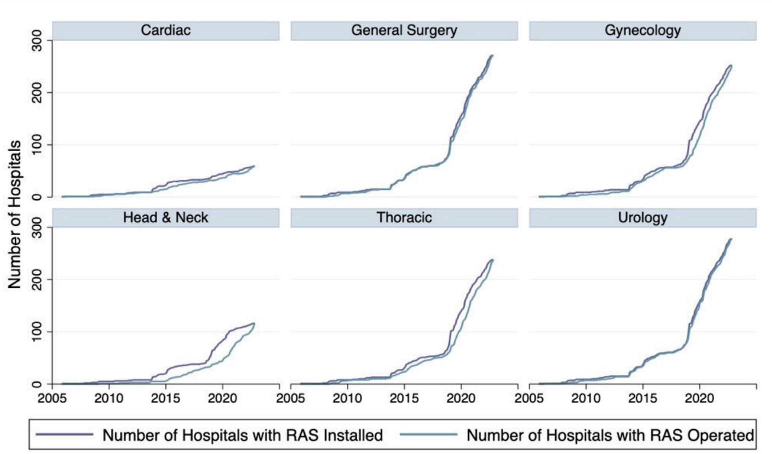


图 2 医院各类别安装与首次使用时间间隔

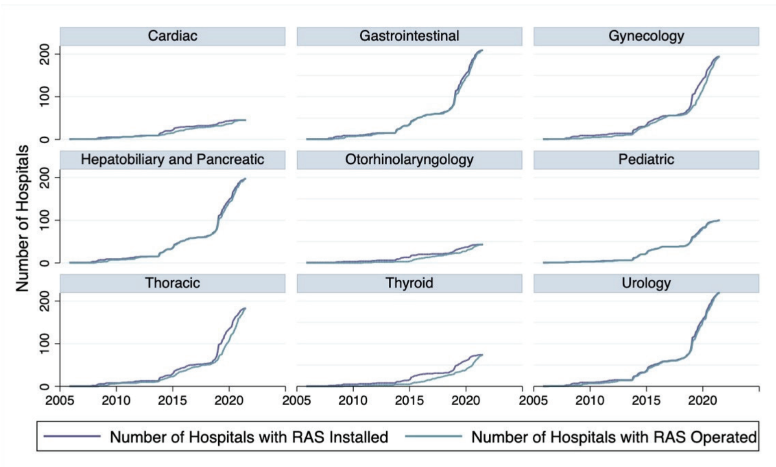


图 3 医院各科室安装与首次使用时间间隔

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机器人手术是否有助于降低胰腺恶性肿瘤的疾病经济负担？一项微观成本研究

武子婷 石茵 张修平*

摘　要　相比于开腹手术，腹腔镜手术和机器人手术具有对人体创伤小、术后恢复快等优点；相比于腹腔镜手术，机器人手术具有手术视野清晰、机械臂灵活、滤抖、有利于精细操作等优点。然而，机器人手术的手术费用高昂，总体而言，机器人手术是否有助于降低患者的经济负担仍不得而知。本研究拟从医疗机构和全社会角度评估：与腹腔镜和开腹手术对比，机器人辅助胰十二指肠切除术治疗胰腺癌的疾病经济负担。本研究采用回顾性横断面研究设计，入组患者为2006年至2023年12月期间在中国人民解放军总医院通过机器人手术和腹腔镜手术，行胰十二指肠切除术的胰腺癌患者。收集其直接成本和间接成本。数据调取和分析工作正在进行中。

一、数据调取

针对临床诊疗、手术和院内费用信息，本研究拟在合作医院中国人民解放军总医院（301 医院）授权下，对接医院内部系统数据，开展收集分析。

目前合作中心 301 医院已完成协议签订和伦理审批。数据申请审批已批复，目前等待 301 医院信息科进行院内成本等相关数据调取。

二、随访方式

本研究拟采取电子问卷方式，聘用问卷调研人员使用个人移动设备完成相关电子问卷的填报，获取院外医疗成本，直接非医疗费用和间接成本，于出院后 0 ～ 5 天对所抽取样本调查入院至调查之日的成本信息，于出院后 30 ～ 35 天，60 ～ 65 天和 90 ～ 95 天对所抽取样本调查近 30 日内的成本信息。

经与 301 医院初步沟通，以上随访拟交由医院研究生实施，由北大团队负责培训问卷内容。

* 武子婷（通信作者），北京大学全球健康发展研究院（E-mail：wuziting@pku.edu.cn）；石茵，中南大学湘雅医院药学部，中南大学湘雅医院老年疾病国家临床研究中，北京大学全球健康发展研究院（E-mail: shiyin910515@csu.edu.cn）；张修平，中国人民解放军总医院肝胆胰外科，中国人民解放军肝胆外科研究所，中国人民解放军数字肝胆外科重点实验室（E-mail: xiupingzhang@aliyun.com）。

三、扩充研究中心

经与 301 医院沟通，拟在对 301 医院回顾性数据初步分析的基础上，进一步扩充研究中心，以增加研究样本的全国代表性。未来本课题组将进一步协商确定中心扩充方式。

初步方案包括：

1. 增加一至两家手术体量较大的研究中心，此方案优点是大中心在较大程度上涵盖了我国的胰腺恶性肿瘤机器人手术样本，研究结果具有更好的全国代表性。但此类研究中心合作门槛较高。

2. 增加若干家手术体量一般的研究中心，此方案的优点是能够在较短时间内与研究中心达成合作，并有助于评价机器人手术在不同层级医院中的成本差异。但此类研究中心的样本代表性有限。

人工智能与外科职业壁垒:
文献综述

潘聿航 易君健 周清源*

摘　　要　女性在许多领域都会遇到职业壁垒。在本次小短文中，我们回顾了女性职业壁垒的归因，并简述既往对于女性职业壁垒的一系列研究。最后，本文简单探讨了为何人工智能可以帮助女性在外科行业中的职业壁垒。

女性在许多领域都会遇到职业壁垒。这些壁垒可以表现为性别偏见、刻板印象、有限的领导职位机会和工资差异等多种形式（例如，Bjerk，2008；Blau and Kahn，2017；Hospido et al.，2022；Lazear and Rosen，1990；Sloane et al.，2021；Winter-Ebmer and Zweimuller，1997；Zhang et al.，2021）。这些壁垒可以归因于劳动力市场的需求和供给两方面。在需求方面，女性受到基于偏好和基于信念的歧视。偏好歧视源于雇主内在的偏好，雇主反感某些群体的人，因此拒绝雇佣他们或只为其提供低于其生产率水平的工资（Becker，1957）。基于信念的歧视包括准确和不准确的统计歧视，这是由于工人的真实生产率对于雇主是不完全信息。因此，雇主依据工人所属社会群体的可观测特征对工人个体的生产率进行统计推断，这往往导致处于劣势群体中的个体受到歧视（Aigner and Cain，1977；Arrow，1985；Bohren et al.，2023；Phelps，1972）。

在供给方面，缺乏女性榜样和文化壁垒也会阻碍女性选择男性主导的领域并成功（Jayachandran，2021；Porter and Serra，2020）。例如，在 Porter 和 Serra（2020）的随机对照实验中，经济学入门课程的学生随机接触了曾在该大学主修经济学的成功而有魅力的女性。研究结果表明，接触女性榜样显著提高了女学生进一步选择其他经济学课程的概率，并且使她们主修经济学专业的概率增加了 8%。Bertrand 等（2021）发现，对妻子收入超过丈夫厌恶的性别认同，会影响妻子的劳动力参与和家庭生产分工。Goussé，Jacquemet 和 Robin （2017）发现，在更传统的家庭中，女性会花更多的时间在家庭生产上。Adda，Dustmann, 和 Stevens（2017）认为，生育导致了女性技能流失、收入损失，以及选择更方便照顾孩子的职业。

* 潘聿航：北京大学全球健康发展研究院（E-mail: yhpan@pku.edu.cn）；易君健：北京大学国家发展研究院和全球健康发展研究院（E-mail: junjian@nsd.pku.edu.cn）；周清源：北京大学经济学院（E-mail: qingyuanzhou.econ@gmail.com)。

外科是女性面临职业壁垒最严重的领域之一（Schizas et al.，2022; World Health Organization，2019）。根据中国外科医师学会在 2019 年对 30 个省、市和自治区的调查，女性仅占所有外科医生 的 6.04%（Bai，2021）。即使在发达国家，这一比例仍然很低，介于 10% 到 20% 之间（Burgos and Josephson，2014）。正如 Schizas 等（2022）所强调，尽管女医学生的数量不断增加，外科仍然是男性主导的领域。通过对一些女外科医生的调查，Epstein（2017）发现女外科医生在学术机构中担任系主任或全职教授的比例有限。为探究导致这些职业壁垒的潜在因素，一些研究利用问卷调查来了解供给侧的信念。Zhou 等（2022）指出，大多数对外科医生职业不感兴趣的女性受访者认为，导师更偏好男性候选人。外科领域的男性被几乎所有认为女性不适合从事外科工作的受访者作为首要原因。Richardson 和 Redfern（2000）以及 Gargiulo、Hyman 和 Hebert（2006）还认为，外科缺少女性榜样以及将外科视为“老男孩俱乐部”也导致了女性不愿从事外科工作。此外，认为外科缺少生活与工作的平衡，以及外科对体力要求高的认知也阻碍了女医学生选择外科（Rohde et al.，2016; Bai，2021）。因此，对工作、雇主和自身的错误认知都导致外科性别比例失衡。另一个问题是女外科医生的不孕率和妊娠并发症的发病率较一般人群更高（Anderson and Goldman，2020）。另一些研究用定性的方法总结了性外科医生面临的主要挑战。例如， Schizas 等（2022）和 Stephens 等（2020）将职业壁垒分为性别歧视、性骚扰、学术晋升、领导能力、工作与生活平衡、体力要求、妊娠困难和性别薪酬差距等方面。然而，与男同事相比，女性外科医生可能具有相似甚至更好的手术结果（Tsugawa et al.，2018；Wallis et al.，2017）。例如，Wallis 等（2017）指出，没有证据表明接受男外科医生和女外科医生治疗的患者的住院时间、并发症和再入院率有所不同，而男外科医生的患者往往具有更高的 30 天死亡率。此外，Roter 和 Hall（2004）发现，女医生的门诊时间平均比男医生长两分钟，在此期间，女医生进行了更多以患者为中心的沟通。女医生还会进行更积极的交流、心理咨询，以及情感导向的对话。

技能偏向性技术变革可以通过多种方式改变女性所面临的职业壁垒。首先，技术进步可以改变性别规范，从而降低女性所面临的文化壁垒。然而，性别规范的改变通常缓慢。已有文献主要关注农业技术对性别劳动分工和性别角色的长期影响。在 Boserup（1970）的开创性研究中，她认为在犁耕农业活动中，男性在上肢和握力方面相对于女性具有比较优势。因此，历史上男性在养家糊口方面扮演了更为主导的角色，导致了现在劳动市场上的性别差距。Alesina、Giuliano 和 Nunn（2013）因果地识别了劳动密集型的轮耕和资本密集型的犁耕对女性就业、政治参与、创业和性别角色态度等方面的影响。类似地，Xue（2016）研究了中国棉纺业技术革命期间

织造技术的引入和对于女性能力偏见的变化之间的关系。这些研究揭示了技术变革对性别动态变化和社会认知的影响。随着手术机器人的引入，做外科手术对体力的需求减少，从而可能削弱男性的比较优势，并重塑性别角色态度。其次，机器人的应用被认为与劳动生产率的提高有关（Graetz et al.，2018）。在外科手术方面，机器人技术的利用可能会缩短手术持续时间，从而使女性更好实现工作与生活的平衡。这反过来可能有助于促进女性进入外科科室。

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达芬奇手术机器人治疗早期非小细胞肺癌成本效果研究

高天夫*

摘　要　肺癌作为我国发病率和死亡率最高的恶性肿瘤，给社会带来了极大的疾病和经济负担。非小细胞肺癌约占肺癌患者的85%，对于早期非小细胞肺癌患者首选手术治疗，包括开胸与微创手术对肺叶进行切除。达芬奇机器人手术系统与传统胸腔镜相比具有术中出血量更少、淋巴结清扫更彻底和预后更好等优势。本研究从医疗卫生体系视角，搭建分区生存模型，系统评估达芬奇机器人手术与胸腔镜手术治疗早期非小细胞肺癌的成本效果。

一、研究背景

肺癌作为我国发病率和死亡率最高的恶性肿瘤，严重危害人民健康，给社会带来了极大的疾病和经济负担。数据显示，2022 年我国新发肺癌患者约 87 万人，肺癌死亡患者 76 万人，居于世界首位（Xia et al.，2022；Cao et al.，2019）。据统计，2020 年我国肺癌患者的经济负担约为 2034 亿元，占我国 GDP 的 0.121%，且呈现逐年上升的趋势（Liu et al.，2021）。肺癌患者中，非小细胞肺癌（non- small cell lung cancer，NSCLC）约占 85%（Yang et al.，2017）。根据中国临床肿瘤学会颁布的《非小细胞肺癌诊疗指南 2023》指出，对于 I 期、II 期 NSCLC 患者首选外科手术，包括开胸与微创手术对肺叶进行切除。随着微创手术技术的发展与进步，肺癌手术已经从早期的开胸手术过渡为胸腔镜手术，但腔镜手术对一些复杂的肺癌手术情况仍存在一定局限性。达芬奇机器人手术系统利用其三维光学，多角度的机械臂操作，与传统胸腔镜相比具有术中出血量更少、淋巴结清扫更彻底、术后疼痛感更轻、预后更好等优势（Yang et al.，2017；Nguyen et al.，2020；Nelson et al.，2019）。达芬奇机器人作为创新医疗技术在临床中被广泛认同，但由于高昂的手术费用使得该技术并未得到普及。本研究从医疗卫生体系视角，搭建分区生存模型，系统评估达芬奇手术机器人与腔镜手术治疗早期非小细胞肺癌的成本效果。为我国创新医疗技术纳入医保支付提供证据，为完善我国 DRG 支付下创新医疗技术的发展与应用提供参考。

*　天津医科大学肿瘤医院；（E-mail：tianfugary@163.com）

二、模型介绍

本研究基于卫生服务体系的角度，构建分区生存模型，评估达芬奇机器人手术与传统腔镜手术用于治疗I-IIIa期非小细胞肺癌患者的成本效果。本研究利用国际研究报告的无进展生存（Progression free survival，PFS）和总生存（Overall survival，OS）曲线，将患者的健康状态分为无进展生存状态、进展生存状态和死亡状态，并根据PFS和OS生存曲线来估计每个确定时间点上各状态的人数比例（Delea et al.，2015）。为评估肺癌手术患者长期健康与成本结果，本研究分别采用exponential、Weibull、log-logistic、log-normal、Gamma、Gompertz回归模型对PFS和OS曲线进行拟合与外推，并挑选出拟合程度最好的回归模型测算肺癌患者术后10年的健康与成本产出。

三、成本和效用值

本研究成本数据来自天津医科大学肿瘤医院病案首页、医保结算清单和医嘱数据测算获得。天津医科大学肿瘤医院肺癌手术3000余例/年，其中达芬奇机器人肺癌手术500余例/年。患者主要来自黑龙江、吉林、辽宁、内蒙古、河北、山东、天津等中国北方地区，样本量充足且可以较好代表中国北方地区肺癌患者人群。

本研究临床数据来源于2020年美国Peter J. Kneuertz发表的单中心回顾性研究（Kneuertz et al.，2020)。该研究涵盖2012-2017年在该中心进行肺癌手术患者临床数据并进行长期随访，最终纳入达芬奇机器人手术组245人，腔镜手术组118人。目前尚未有文献公布达芬奇机器人手术治疗肺癌患者的效用值，Runsen Jin基于上海瑞金医院开展的对比机器人和胸腔镜肺叶切除术的临床试验研究结果显示，两组患者术后48周内健康相关生命质量相似（Jin et al.，2022；Jin et al.，2023）。因此本研究假设机器人手术与胸腔镜手术患者PFS、PD的效用值相同，效用值数据来自2016年Morten Bendixen发表的关于胸腔镜肺癌手术临床试验结果（Bendixen et al.，2016）。最终本研究采用PFS效用值为0.815，PD效用值为0.473。

四、研究指标

本研究主要健康结果指标包括：PFS、OS、QALYs，成本指标包括：手术费、检查费、治疗费、耗材费、其他费用、无进展期医疗费用、进展期医疗费用、二线治疗费用等。最终计算增量成本效果比（incremental cost-effectiveness ratio, ICER）。

五、敏感性分析

本研究采用单因素敏感性分析和概率敏感性分析来检验模型的稳健性。单因素敏感性分析用于检验单个输入参数值对结果的影响，。概率敏感性分析用于模拟多个不确定性参数同时发生变化时对结果的影响，采用蒙特卡洛模拟重复抽样 1000 次，计算每次抽样的 ICER 值。

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技术、技能和治疗效果:外科手术中的机器人

Elena Ashtari Tafti *

监管机构和政策制定者非常关注在服务获取和质量方面的不平等性。医疗保健领域不平等性尤其受到关注，而即使控制了患者风险之后，不同地区和医疗机构之间的患者预后差异仍然存在（Skinner，2011）。医疗提供者使用替代疗法可能部分解释了这一现象（Tsugawa et al.，2017；Birkmeyer et al.，2013）。然而，健康结果似乎只受到上述原因的轻微影响（Molitor， 2018）。事实上，医疗服务提供者技能的异质性可能是这种差异的根源（Chandra and Staiger， 2020；Hull，2018；Chandra and Staiger，2007）。

在本文中，我研究了机器人在减少患者预后变化方面的潜力。无论是职业之间还是职业内部，个人的技能水平差异很大，医疗保健提供者如外科医生和医生，也是这样的（Chan et al.，2022；Currie and MacLeod，2017；Kolstad，2013）。服务提供者技能的差异会产生不平等，并可能加剧获得服务的系统性差异（Finkelstein et al.，2016；Chandra and Skinner，2003； Deaton，2003）。我将证明，在英国，机器人的普及与平均手术表现的提高与高技能和低技能外科医生之间的水平趋同是相吻合的。我利用机器人地理分配中的准随机变化来研究这是否归因于采用机器人手术。通过使用前列腺癌患者的管理数据（前列腺癌是英国男性中最常见的癌症类型），我证明了机器人在这一过程中发挥了重要作用。

我的部分贡献是在处理效应异质性和选择问题存在的情况下确定该技术的影响。迄今为止，与更具侵入性的替代手术相比，机器人手术改善患者预后的医学证据是不确定的（Coughlin et al.，2018；Yaxley et al.，2016；Robertson et al.，2013；Bolla et al.，2012）。现有的研究基于小样本和选择性样本（Neuner et al.，2012），并不是为了确定因果关系（Ho et al.，2013）。如果机器人手术提高手术表现的潜力取决于手术技巧，那么小样本研究只能反映部分情况。此外，假设该技术在技能分布上也是异质的。在这种情况下，我们只能证明治疗效果是和采用者的特征相关联，而不是和技术本身相关联。重要的是，当治疗效果不同时，外科医生和患者可能会根据各自的具体技术收益来选择机器人（Bjorklund and Moffitt，1987）。在这种情况下，如果对机器人的采用是由未观察到的因素决定，那么对机器人手术和传统手术进行回归调整后的比较会导致错误的估计。

为了确定因果关系，我使用了由 Bjorklund 和 Moffitt（1987）介绍并由 Heck-

* 慕尼黑大学（E-mail: elena.ashtari@econ.lmu.de)。

man和Vytlacil（2005）推广的方法，该方法专注于边际治疗效应（MTE）。MTE是在机器人手术和传统手术之间的边际差异下，机器人对个体结果的平均影响。通过这种方法，我确定了机器人对患者结果的因果影响，以及这些影响如何取决于手术技能。我比较了两个患者结果：恢复速度（即术后住院时间）和手术不良事件的发生（即术后发病率）。这是对医生、患者和政策制定者都很重要的手术表现的两个维度（Lotan，2012），机器人手术应该对他们产生可衡量的影响，因为它提高了精度，需要更小的切口（Higgins et al.，2017；Coelho et al.，2010；Lowrance et al.，2010；Nelson et al.，2007）。我通过使用外科医生病人治疗结果的单一风险调整指标来衡量技能。因为机器人可能会影响外科医生的表现，所以我使用了国家引进这项技术之前几年的数据来估计这个指标。事实上，该指标是在所有手术都没有技术辅助的情况下进行的，不受外科医生是否采用技术辅助行为的影响。在大多数情况下，在MTE框架中确定因果关系并不需要比标准工具变量方法更强的假设，但会给工具带来更大的挑战（Cornelissen et al.， 2016）。实际上，这种方法要求至少有一个工具变量是连续的。我利用机器人的交错采用的方法，构建了两种可以满足识别条件的工具。

我发现机器人手术提高了外科医生的表现。机器人减少了术后患者的住院时间和发病率。然而，我的分析表明，这些影响是高度异质性的，技术的进步很大程度上取决于外科医生的技能。高技能的外科医生从这项技术中获益最少，而低技能的外科医生从中获益最多。这一结果表明，机器人在外科医生的技能方面的回报是递减的，这意味着它比高技能的外科医生更能补充低技能的外科医生。在传统手术中，高技能外科医生的患者比低技能外科医生的患者发生不良事件的可能性低4个百分点。然而，有了机器人，他们经历这些事件的可能性降低了大约一个百分点。恢复速度也出现了类似的模式。随着高水平和低水平外科医生在病人治疗结果上的差异缩小，我的分析表明，机器人可能会减少病人治疗结果的差异。也就是说，我发现了一种强烈的逆向选择模式。高技能的外科医生更频繁地使用这项技术，而低技能的外科医生使用较少，尽管他们的回报更高。采用该技术的不同实际或感知成本可以解释这一结果（Suri，2011）。

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北京大学全球健康发展研究院
地址:北京市海淀区颐和园路5号100871
邮箱:ghd@pku.edu.cn
电话:+86 10 6275 7318
网址:www.ghd.pku.edu.cn

PKU Institute for Global Health and Development
5 Yiheyuan Road, Haidian District Beijing, China,100871
E-mail: ghd@pku.edu.cn
Office : +86 10 6275 7318
Website: www.ghd.pku.edu.cn