BMC Surgery

RESEARCH Open Access

Clinical comparative study of robot-assisted and traditional laparoscopic surgery in patients with cervical cancer: a retrospective cohort study

Lijuan Zhang[1†], Lihong Yang[1†], Yan Wang[1], Minghong Sun[1] and Yi Tao[1*]

Abstract

Background A new era in minimally invasive surgery has been ushered in by Leonardo's robot surgical system, but the safety and effectiveness in cervical cancer is lake of evidence. This study aimed to compare the safety, effectiveness, and cost-effectiveness of robot-assisted laparoscopic radical hysterectomy (RRH) and conventional laparoscopic radical hysterectomy (LRH) in patients with cervical cancer.

Methods Patients with cervical cancer who had radical surgery at the first affiliated Hospital of Chongqing Medical University between January 2017 and June 2022 were enrolled. Patients in the LRH and RRH groups were matched 1:1 using propensity score matching (PSM), all patients were followed up to September 2023, cancer recurrence occurred or death, whichever came first.

Results 522 cervical cancer patients were enrolled in this study, 261 of whom were in the LRH group and 261 of whom were in the RRH group. Univariate analysis showed that the RRH group had less intraoperative blood loss, shorter operation time and hospital stay, lower incidence of composite complications and urinary retention, but had higher hospitalization costs. Multivariate Logistic regression analysis showed that LRH was an independent protective factor for composite complications (OR 1.531; 95%CI,1.022 to 2.295; $P = .039$). Cox regression analysis with cancer recurrence as the endpoint showed that LRH (HR 0.320; 95%CI,0.255 to 0.401; $P < .001$) and longer operation time (HR 0.995; 95%CI,0.993 to 0.997; $P < .001$) reduced 68% and 5% risk of cancer recurrence ; results also indicated that the older age (HR 1.017; 95%CI,1.007 to 1.027; $P = .001$) and postoperative complications (HR 22.410; 95%CI,16.019 to 31.350; $P < .001$) would increase 224% recurrence risk of cancer recurrence.

Conclusions Both LRH and RRH demonstrated good short-term efficacy, with RRH outperforming LRH in terms of reduced intraoperative bleeding, shorter hospital stays and operation times, and fewer composite complications. However, the RRH group faces a higher risk of early cancer recurrence and incurs greater expenses. In summary,

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comprehensive long-term prospective studies are needed to thoroughly explore the effectiveness and safety of both LRH and RRH.

Keywords Cervical cancer, conventional laparoscopic radical hysterectomy, Robot-assisted laparoscopic radical hysterectomy, Cost-effectiveness, HPV infection

Background

With an estimated 600,000 new cases and 340,000 deaths annually, cervical cancer is the second most frequent malignancy among women worldwide, and approximately 58% of these deaths occur in Asia [1, 2]. According to the statistics of the World Health Organization (WHO) figures, the number of cervical cancer patients and deaths in China were approaching 110,000 and 60,000, which accounted for about 20% of the world's in 2020, and the number of cervical cancer cases is continually rising [3, 4]. Cervical cancer, the fourth most common cause of cancer-related deaths among women globally, not only endangers women's health but also adds to the medical and financial burden on a global scale [5]. According to studies, more than 93% of cervical cancer cases among women can be attributed to high-risk HPV infections in their medical histories [6]. In the mainland of China, the overall infection rate of high-risk HPV in women is as high as 19.0% [7]. It is particularly noteworthy that HPV 16 and 18 accounting for about 70% of all high-risk HPV infections [8, 9]. Currently, laparoscopic or open total hysterectomy are the primary methods used to treat cervical cancer, and aggressive surgery is the first choice.

A great number of studies have shown that there was almost no difference between minimally invasive surgery represented by laparoscopy and open surgery in thoroughness of tumor resection [10–12]. However, in terms of surgical trauma, incidences of postoperative complications, patient recovery, hospital stay etc., minimally invasive surgery showed distinctive advantages [13–16]. A new era of minimally invasive surgery was ushered in by Leonardo's robot surgery system, yet, different studies showed different results in pros and cons when compared with the traditional laparoscopic surgery. Kim's study found that the recurrence rate in the RRH group was lower than that in the LRH group, but the difference was not statistically significant [17]. In laparoscopic total hysterectomy for the treatment of endometriosis, robot-assisted surgery reduces blood loss, but the operation takes longer [18]. Additionally, a previous study revealed that robot-assisted surgery can significantly lower the risk of complications when compared to traditional laparoscopic surgery for rectal cancer [19]. A study comparing robot-assisted and conventional abdominal herniation revealed that the former could reduce convalescence [20]. However, research comparing traditional laparoscopic gastrectomy versus robot-assisted gastrectomy showed no difference in intraperitoneal infection complications between the two operating methods [21]. Additionally, Kim et al. indicated that there is no clear benefit to robot-assisted surgery in terms of lowering the postoperative incidence of rectal cancer patients and enhancing intestinal function and quality [22].

Although numerous studies have compared Leonardo's robot-assisted surgery with traditional laparoscopic surgery, few have prospectively compared them in radical resection of cervical cancer. To compare the effectiveness, safety, and economic advantages of Robot-Assisted Laparoscopic Radical Hysterectomy (RRH) versus Traditional Laparoscopic Radical Hysterectomy (LRH), we conducted this study. Our objective was to provide a solid foundation for cervical cancer patients to make the most suitable surgical choice.

Methods

Study design

This is a retrospective cohort study. All patients were followed up to September 2023, recurrence occurred or death, whichever came first. The objective is to conduct a comprehensive assessment of these two surgical approaches by analyzing the recurrence rates, complications, and cost-effectiveness between the two groups.

Patients

Patients diagnosed with cervical cancer at the First Affiliated Hospital of Chongqing Medical University between January 2017 and June 2022 who underwent radical hysterectomy were screened. The inclusion criteria was as follows: (1) pathologically diagnosed with cervical cancer; (2) prep for radical hysterectomy; (3) have complete clinical pathology and medical records. The exclusion criteria were as follows: (1) patients aged <18 or ≥ 80 years; (2) patients who had severe diseases and other malignancies; (3) patients who converted from laparoscopic surgery to laparotomy. Patients meeted the inclusion criteria will be contacted and given informed consent to participate in this cohort study. This study was approved by the Ethics Committee of the first affiliated Hospital of Chongqing Medical University (No. 2022-K439), data collecting conforms to STROCSS 2021 standard [23].

Data collection

We collected data from the Electronic Medical Record of the first affiliated Hospital of Chongqing Medical University. Demographic and presenting characteristics

included age, BMI, history of abdominal surgery (no, yes), cancer classification (squamous cell carcinoma, adenocarcinoma, other type), tumor staging (I,II,III and above), recurrence of cancer (no, yes); the details of the operation included the operation duration and intraoperative blood loss; other variables included the length of stay in hospital, the hospitalization costs recorded by the outpatient payment system and complications (composite complications, fever, infected, intraoperative injury, poor healing of the vaginal stump, Lower extremity venous thrombosis, urinary retention, Intestinal obstruction).

We defined axillary temperature higher than 37.2 ℃ as postoperative complication fever. Infection is defined as emerging physical signs or culture-positive. Intraoperative organ/ tissue injury is defined as injury found during operation or confirmed by postoperative disease. Poor healing of vaginal stump is defined as irregular vaginal bleeding and poor vaginal healing confirmed by gynecological examination. Lower extremity venous thrombosis is defined as lower extremity venous thrombosis confirmed by color doppler ultrasound. Urinary retention is defined as a radiographic or clinically proven bladder filled with urine and cannot be discharged normally. Intestinal obstruction is defined as a disturbance of passage of intestinal contents for any reason confirmed by clinical manifestations or imaging. The abnormal cell types were classified by pathological examination, the cancer stage was categorized according to FIGO staging (2009) [24].

We investigated cancer recurrence throw telephone follow-up. Cancer recurrence was defined as postoperative local or distant recurrence, which was confirmed by pathology or imageology. The follow-up period was defined as the duration from the initial visit until either September 2023, recurrence, or death, whichever occurred first.

Statistical analyses

We used propensity score matching (PSM) to reduce the differences in baseline characteristics between the two groups of patients. Logistic regression was used to calculate the density score, and the nearest neighbor matching method was used to match patients at 1:1 without replacement, the matching variables were age, BMI, cancer classification and tumor stage. The caliper radius was set to a standard deviation of 0.1 to prevent mismatch. Standardized differences were estimated before and after matching to evaluate the balance, the value less than 0.05 indicates that there is a balance between groups.

Categorical data were presented as number (frequencies) and analyzed using 2-tailed X^2 tests or the Fisher exact test. Continuous variables were presented as (means ± SD), if normally distributed and medians and IQRs if not, groups were compared with *t*-test or Kruskal-Wallis test. A binary Logistic regression model was used to determine the independent risk factors of postoperative complications. The risk of cancer recurrence was analyzed with Cox proportional-hazards model, we calculated the hazard ratio, corresponding 95% confidence interval. Kalplan-Meier method and log-rank test were used to analyze the incidences of cancer recurrence rates of the groups.

All data were analyzed using SPSS 27.0. A two-sided P value of less than 0.05 was considered to indicate statistical significance.

Results

Patient screening process

Flow diagram of patients was shown in Figs. 1 and 922 patients diagnosed with cervical cancer were screened in the first affiliated Hospital of Chongqing Medical University from January 2017 to June 2022. A total of 522 patients were enrolled in this study, RRH group (n=261) and LRH group (n=261) were matched by PSM (Figure 1).

Clinical baseline characteristics of patients

The baseline and clinical characteristics of the two groups were almost balanced. However, patients with previous abdominal surgery in RRH (101(38.7%)) was significantly higher than that in the LRH group (79(30.3%)) (P=.043). The intraoperative blood loss in the RRH group(80(50,100)mL) was significantly less than that in the LRH group(100(60,180)mL) (Table 1).

Description of cancers

See from Fig. 2, squamous cell carcinoma, adenocarcinoma and other types of cancer accounted for 84.5%, 13.6%, and 1.9% respectively. See from Fig. 3, a total of 486 patients perfomed HPV test, of which 441 (84.5%) were HPV positive. Overall, the top three HPV subtypes were HPV16, 18, and 58, accounting for 60.1%, 9.8% and 4.8% respectively.

Cost and hospital stay of the two groups

See from Table 2, the median operation time and the hospital stay of the RRH group was shorter than that of LRH group. However, the median hospitalization cost in the RRH group was significantly higher than that in the LRH group (P<.001).

Occurrence of complications

The incidence of composite complications (21.8%) and urinary retention (3.1%) in the RRH group were lower than LRH group (composite complications 29.5%, urinary retention 6.9%). However, there was no significant difference in fever, infection, poor healing of vaginal stump,

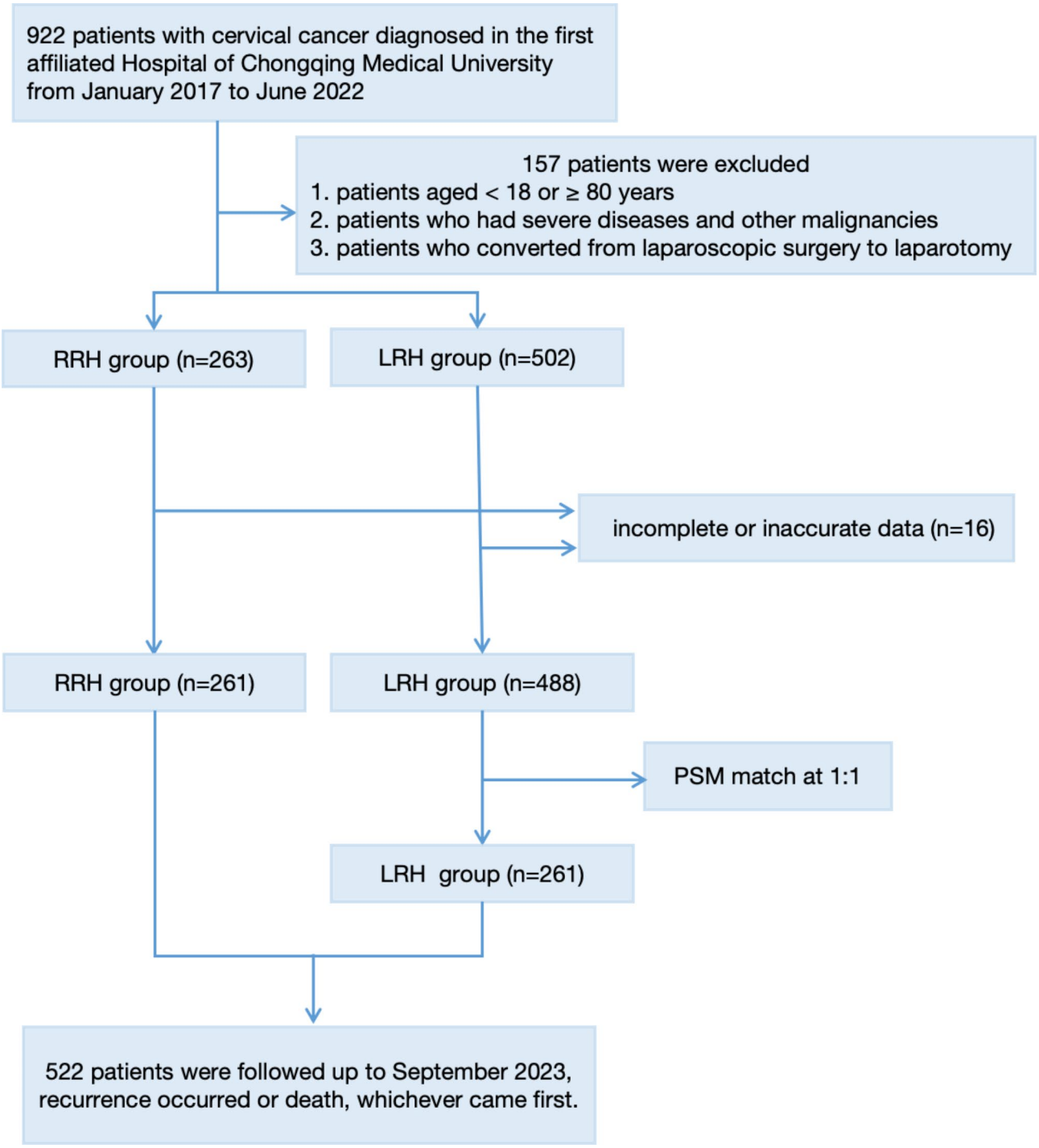

Fig. 1 Flow diagram of patients

lower limb venous thrombosis, and intestinal obstruction between two groups (Table 3).

Influencing factors of complications

Six variables including operation method, age, BMI, cancer classification, tumor stage, and history of abdominal surgery were selected as independent variables and included in multiple logistic regression analysis. After adjusting for covariance, the operation method was independently related to the occurrence of complications, RRH could significantly reduce the incidence of complications (OR 1.531; 95%CI,1.022 to 2.295; P=.039) (Table 4).

Table 1 Demographic and clinical characteristics of two groups

Variable	RRH group($n=261$)	LRH group($n=261$)	*P*-value
Age	49.88 ± 9.89	49.98 ± 10.05	0.909
BMI (Kg/m^2)	23.44(21.08,26.04)	23.93(22.05,25.81)	0.349
Cancer classification			0.160
Squamous cell carcinoma	218(83.5)	223(85.4)	
Adenocarcinoma	35(13.4)	36(13.8)	
other type	8(3.1)	2(0.8)	
Tumor staging			0.689
I	102(39.1)	106(40.6)	
II	145(55.6)	145(55.6)	
III and above	14(5.4)	10(3.8)	
History of abdominal surgery			0.043
No	160(61.3)	182(69.7)	
Yes	101(38.7)	79(30.3)	
Intraoperative blood loss(mL)	80(50,100)	100(60,180)	< 0.001
Recurrence of cancer			0.459
No	254(97.3)	251(96.2)	
Yes	7(2.7)	10(3.8)	

Note: Values are presented as (means ± SD), median (interquartile range) or number (%). LRH, traditional laparoscopic radical hysterectomy; RRH, robot-assisted laparoscopic radical hysterectomy

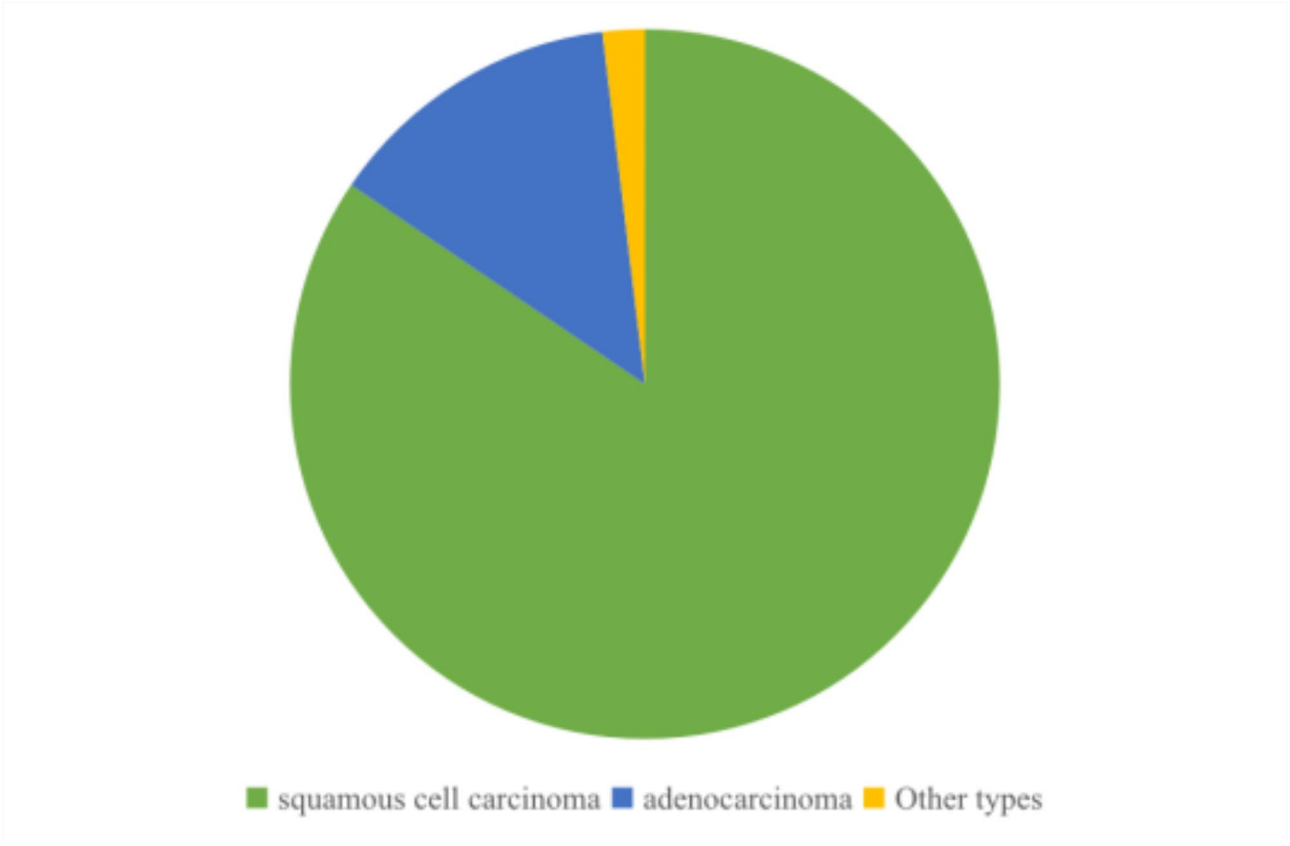

Fig. 2 Cancer classification of patients

Influencing factors of cancer recurrence

Cox proportional-hazards model was performed to evaluate the risk of cancer recurrence (Table 5). In multivariable analysis, older age (HR 1.017; 95%CI,1.007 to 1.027; $P=.001$) and postoperative complications (HR 22.410;95%CI,16.019 to 31.350; $P<.001$) were related to the increased risk of cancer recurrence. LRH (HR 0.320; 95%CI,0.255 to 0.401; $P<.001$) and longer operation time

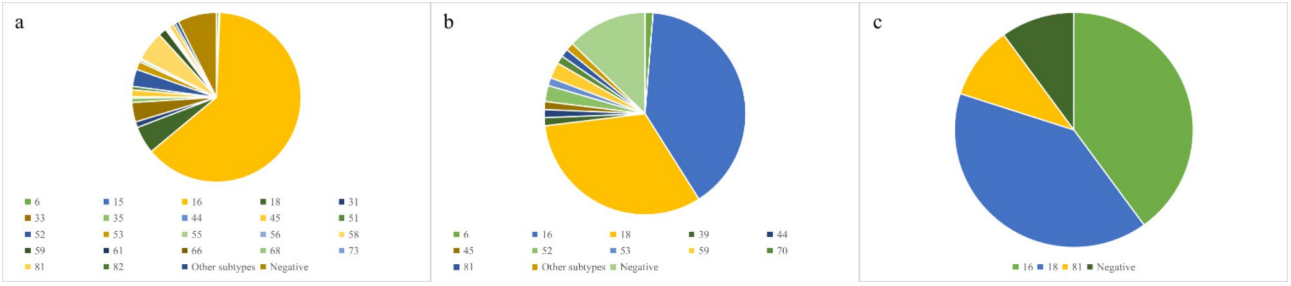

Fig. 3 The composition of HPV subtypes among different cancer types
Note: **a**, **b**, and **c** represent the distribution of HPV subtypes in squamous carcinoma, adenocarcinoma and other type of cancer

Table 2 Cost and hospital stay of the two groups

Variable	RRH group (*n* = 261)	LRH group (*n* = 261)	*P*-value
Duration of operation (minutes)	152.00(125.00,184.50)	205.00(175.00,250.00)	< 0.001
Length of stay (days)	13.57 ± 4.19	14.97 ± 3.84	< 0.001
Hospitalization expenses (yuan)	55508.02(52292.33,61876.62)	39621.77(33468.52,54436.17)	< 0.001

Note: Values are presented as (means ± SD), median (interquartile range) or number (%). LRH, traditional laparoscopic radical hysterectomy; RRH, robot-assisted laparoscopic radical hysterectomy

Table 3 Complications of two groups

Variable	RRH group (*n* = 261)	LRH group (*n* = 261)	*P*-value	RR (95%CI)
Composite complications	57(21.8)	77(29.5)	0.045	0.740(0.550,0.996)
Fever	24(9.2)	25(9.6)	0.881	0.960(0.563,1.636)
Infected	17(6.5)	14(5.4)	0.579	1.214(0.611,2.412)
Intraoperative injury	5(1.9)	2(0.8)	0.450	2.500(0.489,12.770)
Poor healing of the vaginal stump	1(0.4)	3(1.1)	0.624	0.333(0.035,3.184)
Lower extremity venous thrombosis	7(2.7)	7(2.7)	1.000	1.000(0.356,2.811)
Urinary retention	8(3.1)	18(6.9)	0.044	0.444(0.197,1.004)
Intestinal obstruction	2(0.8)	5(1.9)	0.450	0.400(0.078,2.043)

Note: Values are presented as number (%). LRH, traditional laparoscopic radical hysterectomy; RRH, robot-assisted laparoscopic radical hysterectomy

Table 4 Influencing factors of complications

Variable	Univariate analysis		Multivariable analysis	
	OR(95%CI)	*P*-value	OR(95%CI)	*P*-value
Operation method		0.046		0.039
RRH	1		1	
LRH	1.498(1.008,2.226)		1.531(1.022,2.295)	
Age	1.001(0.982,1.021)	0.902	1.000(0.979,1.021)	1.000
BMI (Kg/m^2)	0.949(0.896,1.006)	0.076	0.946(0.892,1.003)	0.061
Cancer classification		0.898		0.884
Squamous cell carcinoma	1		1	
Adenocarcinoma	0.903(0.503,1.621)	0.733	0.932(0.507,1.713)	0.820
other type	1.229(0.313,4.834)	0.768	1.352(0.333,5.486)	0.673
Tumor staging		0.513		0.493
I	1		1	
II	1.173(0.776.1.773)	0.449	1.190(0.760,1.865)	0.447
III and above	1.622(0.655,4.019)	0.296	1.700(0.663,4.358)	0.270
History of abdominal surgery		0.965		0.852
No	1		1	
Yes	0.991(0.655,1.498)		1.041(0.681,1.592)	

Note: LRH, traditional laparoscopic radical hysterectomy; RRH, robot-assisted laparoscopic radical hysterectomy

Table 5 Influencing factors of cancer recurrence

Variable	Univariate analysis		Multivariable analysis	
	HR (95%CI)	*P*-value	HR (95%CI)	*P*-value
Operation method		< 0.001		< 0.001
RRH	1		1	
LRH	0.422(0.348,0.511)		0.320(0.255,0.401)	
Age	1.017(1.008,1.026)	< 0.001	1.017(1.007,1.027)	0.001
BMI (Kg/m^2)	0.998(0.991,1.006)	0.691	1.000(0.994,1.006)	0.954
Cancer classification		0.993		0.441
Squamous cell carcinoma	1		1	
Adenocarcinoma	1.014(0.786,1.308)	0.917	1.175(0.898,1.538)	0.240
Other type	1.018(0.526,1.971)	0.958	0.853(0.434,1.676)	0.645
Tumor staging		0.022		0.161
I	1		1	
II	1.077(0.898,1.292)	0.424	0.937(0.770,1.141)	0.518
III and above	1.851(1.196,2.864)	0.006	1.428(0.910,2.239)	0.121
History of abdominal surgery		0.478		0.679
No	1		1	
Yes	1.069(0.889,1.284)		0.960(0.790,1.165)	
Intraoperative blood loss	1.000(0.999,1.001)	0.837	1.001(1.000,1.001)	0.114
Duration of operation (minutes)	0.996(0.994,0.997)	< 0.001	0.995(0.993,0.997)	< 0.001
Complication		< 0.001		< 0.001
No	1		1	
Yes	0.106(0.080,0.140)		22.410(16.019,31.350)	
HPV 16		0.591		0.888
No	1		1	
Yes	1.051(0.877,1.259)		1.015(0.825,1.250)	
HPV 18		0.857		0.432
No	1		1	
Yes	1.027(0.769,1.372)		0.879(0.637,1.213)	
HPV 52		0.016		0.448
No	1		1	
Yes	1.816(1.117,2.952)		1.212(0.738,1.990)	
HPV 58		0.046		0.253
No	1		1	
Yes	1.495(1.006,2.222)		1.279(0.839,1.950)	
HPV 59		0.399		0.374
No	1		1	
Yes	1.352(0.671,2.726)		1.386(0.675,2.847)	

Note: LRH, traditional laparoscopic radical hysterectomy; RRH, robot-assisted laparoscopic radical hysterectomy

(HR 0.995; 95%CI,0.993 to 0.997; $P<.001$) were protective factors of cancer recurrence. See from Fig. 4, the Log-rank test showed no difference in cumulative recurrence rate between the RRH group and LRH group, but the recurrence time was earlier in RRH group.

Discussion

Previous research on cervical cancer and other gynecological illnesses has identified age, BMI, and prior abdominal surgical history as key influencing factors for postoperative complications [25]. In this study, we conducted a retrospective cohort analysis, utilizing PSM to control for confounding variables. We examined the baseline and surgical details of 522 cervical cancer patients who underwent either RRH or LRH, and assessed their postoperative complications, operation costs and cancer recurrence rates. Analysis of HPV subtype distribution across different cancer types revealed that 84.5% of cervical cancer patients were infected with HPV, with HPV 16 accounting for 60.1% of these cases. Our findings indicated that patients in the RRH group experienced significantly lower blood loss, shorter operation duration and hospital stays compared to those in the LRH group. However, the hospitalization costs were notably higher for the RRH group. Furthermore, our study identified RRH, composite complications, shorter operation times, and advanced age as risk factors for cancer recurrence.

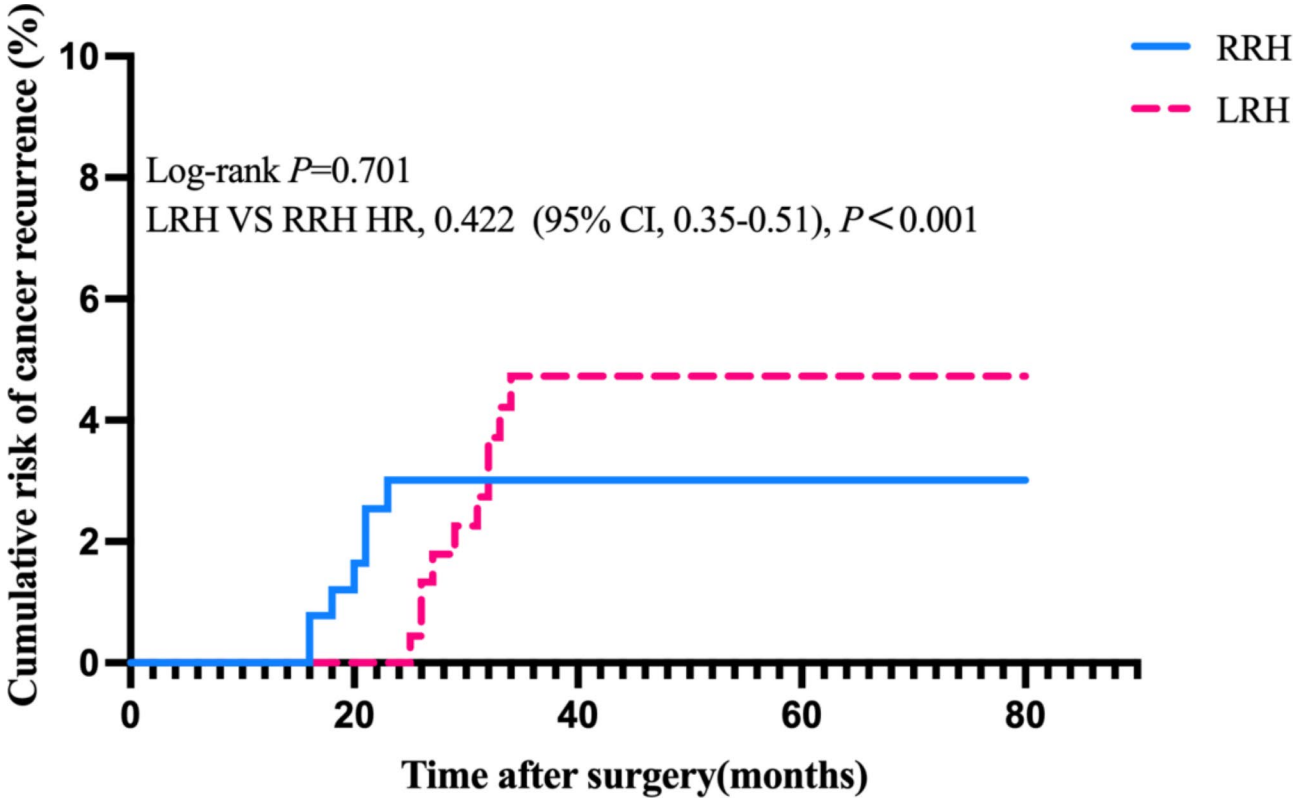

Fig. 4 Kaplan–Meier Estimates of cancer recurrence between RRH group and LRH group

Consistent with the findings of the NIE study [2], our investigation revealed that the operating time for the RRH group was 53 min shorter than that of the LRH group. However, it's worth noting that the median operation time for RRH in another cervical cancer study was 185 min [26], exceeding our research's finding of 152 min. This discrepancy may be attributed to variations in the definition of "duration of surgery" across studies, as well as factors such as the surgeon's laparoscopic experience and expertise. The precision and efficiency of Leonardo's robotic motion control technology can help minimize operation time, but it is not the sole determinant.

Our results align with the majority of research [10, 27, 28] in showing that intraoperative blood loss was lower in the RRH group compared to the LRH group. This can be attributed to the robotic arm's ability to provide high-definition 3D vision with a magnification of 10 to 15 times, maintain stable traction and anti-traction in confined spaces, and prevent slight hand tremor, thereby enhancing surgical field stability, increasing pelvic vessel visibility, and reducing the risk of unintentional blood vessel damage.

Furthermore, our study found that the LRH group experienced 1.531 times more complications than the RRH group, consistent with a recent study [19]. The RRH group also had a lower incidence of composite complications and urinary retention compared to the LRH group. However, as is the case with most research, there was no significant difference between the two groups in terms of infection, postoperative fever, or other complications [21, 29–32]. We speculate that early out-of-bed activities, reduced nerve injury, and bladder interference may contribute to the lower incidence of urinary retention in the RRH group.

Similar to the NIE trial, the RRH group had a shorter duration of stay compared to the LRH group, with average hospital stays of 14 and 15 days, respectively [2]. However, Asian countries had longer hospital stays compared to the Americas, where two investigations on laparoscopic procedures were conducted (one in Canada and one in the Netherlands) [33, 34]. A recent study reported a median hospital stay of just 2 days for RRH patients [26], significantly shorter than our findings. These discrepancies may be due to physical differences across races, national healthcare regulations, or the medical insurance system. The hospitalization expenses for the RRH group appear to be higher than those for the LRH group, potentially due to the high cost of professional training, surgical supplies, and the acquisition and maintenance of Leonardo's robotic system [35]. These factors pose significant barriers to the widespread adoption of robotic surgery.

Consistent with prior research findings, a notable disparity was observed in the recurrence rates between the

LRH group (3.8%) and the RRH group (2.7%) [17, 36]. The risk factors for cancer recurrence identified were age, surgical duration, and composite complications [37]. While HPV-16 and HPV-18 infections have been reported to be linked to cervical cancer recurrence [38], but no such correlation was found in our study. However, it is noteworthy that our findings revealed robotic surgery as a significant risk factor for cancer recurrence, implying that RRH may adversely affect the prognosis of cervical cancer. In a study by Pedro comparing RRH with traditional open surgery (ORH), it was discovered that patients undergoing RRH had a four fold higher risk of cervical cancer recurrence compared to those undergoing ORH [39]. Our results further indicate that, in comparison to LRH or traditional surgery, RRH does not offer a superior long-term prognosis. Additionally, although our Log-rank result showed no significant difference in the overall recurrence rate between the two groups, the trend of the Kaplan-Meier curve suggested that RRH accelerated the recurrence time compared to the LRH group.

Our study has certain limitations, notably being a retrospective cohort study where subjects were selected based on pre-existing data or records. This methodology may introduce information bias due to potential inconsistencies or inaccuracies in the data, and it may also lead to selection bias.

In conclusion, both LRH and RRH have demonstrated favorable short-term efficacy. Specifically, RRH exhibits advantages over LRH in terms of reduced intraoperative bleeding, shorter hospital stays, quicker operation times, and a lower incidence of composite problems. However, the RRH group is associated with a higher risk of early cancer recurrence and increased costs. However, it is imperative to conduct further long-term prospective studies to comprehensively evaluate the effectiveness and safety of LRH and RRH.

Acknowledgements
We extend our gratitude to all participants in this survey for their support and cooperation. We appreciate the successful implementation of this study by all the researchers.

Author contributions
Y.T. designed the study; L.Z., L.Y., Y.W., M.S. conducted the survey; L.Z., L.Y., Y.W., M.S. collected the data; L.Z., L.Y. drafted the manuscript; Y.T. edited the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding
None.

Data availability
Data is available from the authors upon reasonable request.

Declarations

Ethics approval and consent to participate
This study was carried out in accordance with the principles of the Declaration of Helsinki. This study was approved by the Ethics Committee of the First Affiliated Hospital of Chongqing Medical University (No. 2022-K439). Informed consent was obtained from all subjects involved in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no Competing interests.

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Received: 30 October 2024 / Accepted: 10 December 2024
Published online: 27 December 2024

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