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Research article

Robotic-assisted laparoscopic radical hysterectomy for early-stage cervical cancer: The more experienced the bedside assistant, the better?

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ABSTRACT

Background: Aim to investigate the impact of bedside assistant's work experience and learning curve on the short-term safety and efficacy in robotic-assisted laparoscopic radical hysterectomy for early-stage cervical cancer.

Methods: Our research retrospectively retrieved 120 cases of early-stage cervical cancer patients who underwent robotic-assisted laparoscopic radical hysterectomy at the First Affiliated Hospital of Guangxi Medical University. According to the different work experiences of the two bedside assistants (BA), patients were divided into a research group (inexperienced BA 1) and a control group (experienced BA 2). Furthermore, the learning curves of these BAs were plotted separately and divided into two distinct phases by cumulative summation: the first learning phase and the second master phase.

Result: In terms of work experience, comparing BA 1 with BA 2 who was more experienced, although the average operative time was prolonged by 29 min ($P < 0.001$), it did not increase the incidence of operative complication [24.4 % VS 29.1 %, $P = 0.583$], positive resection margin [4.9 % VS 7.6 %, $P = 0.714$], intraoperative organ damage [0 % VS 2.5 %, $P = 0.546$] and there was no significant difference in the number of lymph nodes [19 VS 15, $P = 0.103$]. Additionally, comparing two distinct phases of the same bedside assistant, there was no significant increasing rate in terms of operative complication, positive resection margin, intraoperative organ damage, and the number of lymph nodes ($P > 0.05$) neither BA 1 nor BA 2, except for a slight extension of operative time about 20 min in learning phase ($P < 0.05$).

Conclusion: In robotic-assisted laparoscopic radical hysterectomy for early-stage cervical cancer, work inexperience and the learning phase of BA only result in a slight extension of operative time, without causing worse short-term surgical outcomes.

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1. Introduction

Cervical cancer, as a common malignant tumor in women, is one of the top four causes of female mortality worldwide [1,2]. Surveys conducted in 2020 indicated that there were approximately 604,000 new cases of cervical cancer globally, resulting in an estimated 342,000 deaths annually [3]. All the time, radical hysterectomy has been the standard operation for the surgical treatment of early-stage cervical cancer with surgical approaches mainly including laparotomy or minimally invasive surgery (MIS). Nevertheless, the retrospective study published in NEJM (LACC trial) in 2018 indicated that for early-stage cervical cancer patients, both disease-free survival and overall survival after minimally invasive surgery were significantly lower compared to laparotomy [4]. Subsequently, Niteck et al. similarly reported that MIS increased postoperative recurrence and mortality rates among early-stage cervical cancer patients [5]. In contrast, in 2022, the CIRCOL Group Study showed that survival outcomes were similar between MIS and laparotomy in this large retrospective multicenter cohort [6], which was consistent with the MEMORY study [7]. As a result, the ideal surgical approach for early-stage cervical cancer treatment has become highly controversial in gynecological oncology.

As the exploration of the LACC trial deepens, MIS for early-stage cervical cancer has been noticed again. Robotic-assisted laparoscopic surgery, as one of the minimally invasive surgeries, has gained recognition in gynecological oncology for its superiority of three-dimensional visualization, elimination of hand tremors, and precise and flexible operation [8]. Lowe reported that robotic-assisted laparoscopic radical hysterectomy associated with minimal blood loss and few operative complications offers an alternative to traditional radical hysterectomy [9]. A meta-analysis similarly showed that the survival outcomes are comparable between robotic and laparoscopic radical hysterectomy [10]. Furthermore, a multicenter randomized controlled trial reported that robotic-assisted laparoscopic radical hysterectomy (RACC trial) was non-inferior to laparotomy in terms of disease-free survival and had fewer postoperative complications [11]. While, due to the relatively independent operative pattern between the console surgeon (CS) and the bedside assistant (BA), to ensure better postoperative outcomes, CS is more rigorous and subjectively inclined to choose experienced BAs. To a large extent, this limits the participation of young BA in robotic-assisted laparoscopic radical hysterectomy (RALH). Nevertheless, current research is more focused on the impact of the surgical proficiency and learning curve management of CS [12,13] and neglects the objective analysis of the safety and efficacy of BA in RALH. Currently, some researchers have explored the impact of BAs in other robotic-assisted laparoscopies such as prostatectomy, nephrectomy, hysterectomy, inguinal hernia repair, etc. However, there is no research reporting on the impact of BA experience on the safety and efficacy of RALH surgery. Hence, our research aims to provide objective evidence for the actual impact of BA in RALH and better guidance for the management of BAs and the construction of clinical surgical teams.

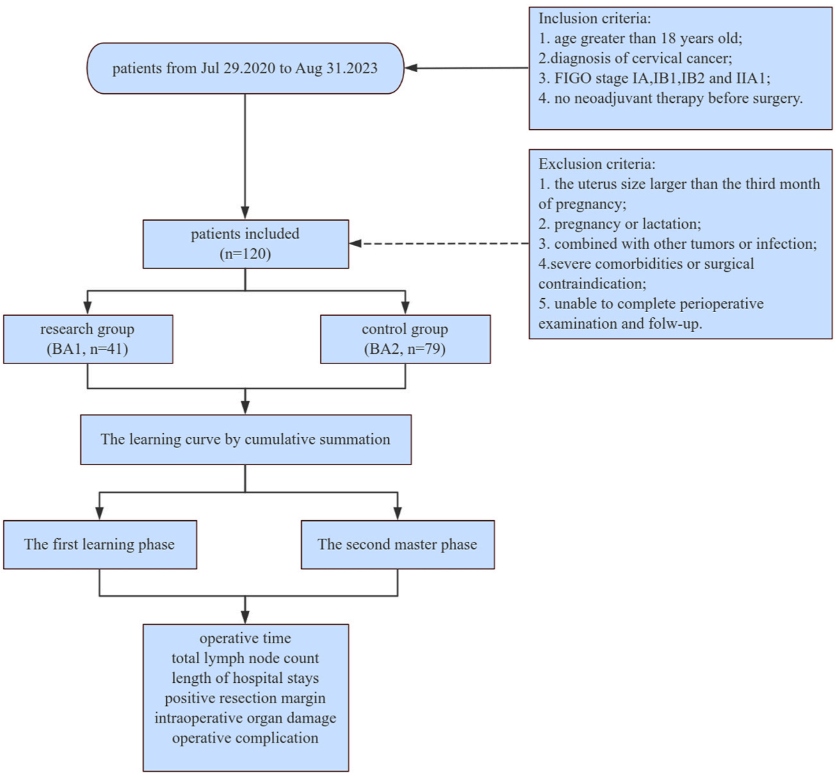

Fig. 1. Study design and inclusion or exclusion criteria.

2. Methods

This was a retrospective cohort study that followed the principles of the Helsinki Declaration. It was approved by the Ethics Committee of the First Affiliated Hospital of Guangxi Medicacervical cancer patients who underwent RALH at the Department of Obstetrics and Gynecology, First Affiliated Hospital of Guangxi Medical University from July 29, 2020, to August 30, 2023.

2.1. Patients

In our study, two senior gynecologic oncologists conducted a preoperative evaluation for each participant according to the 2018 International Federation of Gynecology and Obstetrics (FIGO) stage criteria for cervical cancer [14]. Inclusion criteria: (1) Over 18 years old; (2) Patients diagnosed with cervical cancer for the first time; (3) Stage IA, IB1, IB2, and IIA1 of squamous cell carcinoma, adenocarcinoma or adenosquamous carcinoma of the cervix; (4) Undergoing primary radical hysterectomy; (5) No previous neo-adjuvant therapy. Exclusion criteria: (1) More than uterus size of three months; (2) Pregnancy or lactation; (3) Patients with concurrent other tumors or infection diseases; (4) Patients with severe comorbidities or contraindications which make them intolerable for surgery; (5) Patients unable to cooperate for perioperative examinations and follow-up. Medical records, surgical videos, and operation records were all archived by a dedicated person.

2.2. Study design

All surgeries were performed by a team consisting of the same console surgeon (CS) and one bedside assistant (BA). The sole CS in our study is a high-volume surgeon in the field of gynecological oncology surgery, currently serving as a board member of the Asian Society of Gynecologic Robotic Surgery (ASGRS). This CS has been independently performing robotic-assisted laparoscopic surgery since 2016, with extensive experience. He completes approximately 748 cases of robotic-assisted laparoscopic radical hysterectomy and robotic-assisted laparoscopic hysterectomy. The study included two BAs with different work experiences in gynecology, denoted as BA1 and BA2. Inexperienced BA 1 has less than five years of work experience and has not performed gynecological surgery independently. In contrast, experienced BA 2 has more than ten years of work experience and can independently perform laparoscopic radical hysterectomy. Neither BAs had prior experience in RALH surgery before this study. Based on the working experience of BAs, patients were divided into two groups-the research group and the control group. The research group (41 patients) underwent surgery with BA1, while the control group (79 patients) underwent surgery with BA2 (Fig. 1).

2.3. Clinical data

In this study, we collected relevant data in chronological order starting from the first RALH surgery performed with these two BAs respectively. All data related to preoperative, intraoperative, and postoperative parameters, were obtained from the electronic medical record system of the First Affiliated Hospital of Guangxi Medical University. Preoperative parameters included age, body mass index (BMI), comorbidity, history of previous abdominopelvic surgery, FIGO stage, HPV infection status, pathological staging, grading, and histological type. Intraoperative parameters: (1) operative time: operative time is a vital indicator that objectively reflects the maturity and proficiency of surgical techniques. The operative time of robotic-assisted laparoscopy mainly includes docking time and console time. Current research demonstrates that docking time is generally between 5 and 10 min and is unrelated to the difficulty of the

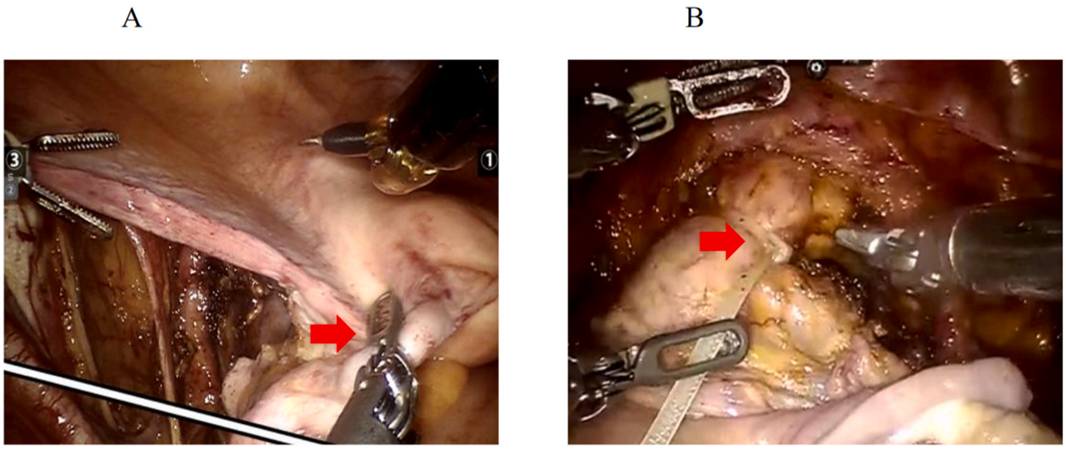

Fig. 2. Fig. 2A was shown that the 3rd robotic arm was installed to substitute uterine manipulator for traction. The red arrow is the 3rd robotic arm. Fig. 2B was shown that vaginal ligation was programmed below the cervical lesion to avoid the implantation and metastasis of tumor cells during cutting off the vagina. The red arrow is vaginal ligation. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

surgery [15]. Considering the higher degree of difficulty and longer operative time associated with RALH, we did not further divide the operative time into separate parts while including the total time from the initiation of the first incision to the closure of the final incision; (2) length of hospital stays: the duration from the surgery date to discharge; (3) lymph node count; (4) intraoperative organ damage; (5) positive resection margin. By the definition of operative-related complication in the National Surgical Quality Improvement Program (NSQIP) database of the American College of Surgeons (ACS), adverse events occurring from the day of surgery to 30 days after surgery are considered operative complications, including infection (surgical site infection, systemic infection, and local infection containing urinary tract infection and pneumonia), wound disruption, need for re-operation, deep vein thrombosis, pulmonary embolism, cardiac arrest, sepsis, etc [16]. Taking into account the unique characteristics of RALH, we compiled the following parameters relevant to postoperative complications: infection, wound disruption, vaginal laceration, deep vein thrombosis, pulmonary embolism, intestinal obstruction, hydronephrosis, ureterovaginal fistula.

2.4. Surgical technique

Based on the reports on robot-assisted laparoscopic surgery, the placement of the operating arms was determined [15]. Current research has revealed that cancer cell spillage during MIS for early-stage cervical cancer can be attributed to various factors including the exposure of tumors, the use of a uterine manipulator, and the direct handling of the uterine cervix [17]. Saini reported that the recurrence rate for patients with intra-operative tumor spillage is 5.6 times higher compared to those without intra-operative tumor spillage [18]. Therefore, to avoid cancer cell spillage, we have modified the surgical procedure. First, we used the third arm of the da Vinci robot surgical system rather than the uterine manipulator to tract the uterus and maintain it in an anterior position by clamping the uterine angle (Fig. 2A). According to our earlier study, using the third arm rather than uterine manipulator did not prolong the operative time and helped reduce the incidence of postoperative complications, such as infection, sepsis, urinary retention, etc [19]. The most significant advantage was that the third arm prevented the lymphovascular dissemination and implantation in the abdominopelvic cavity by compressing cancer tissue using the uterine manipulator [20]. Next, the vagina was closed by placing a vaginal cuff above the incision site before colpotomy (Fig. 2B). Current research suggests that protective colpotomy, such as vaginal closure, vaginal colpotomy, and other potential methods could improve surgical outcomes in minimally invasive radical hysterectomy [21]. Last, after specimen excision, immediately bag all specimens for specimen delivery. The above-mentioned modified surgical approaches which reflect the principle of tumor-free offer better avoidance of tumor cell dissemination compared to traditional laparoscopic radical hysterectomy for cervical cancer.

2.5. Learning curve

The cumulative summation analysis (CUSUM) achieves continuous assessment of data over a while by cumulatively summing the deviations between the raw data and the mean value [22]. CUSUM analysis is an approach used to monitor performance in industrial sectors. Currently, it has now been widely applied to the medical field to facilitate surgical technique management by plotting the learning curve of surgeons during operative procedures such as oncological surgery, plastic surgery, laparoscopic surgery, and so on [22–24]. CUSUM analysis based on operative time can be used to plot the learning curve of BAs and determine the case number required to achieve mastery according to the slope of the learning curve. In our study, First, we recorded the operative time in chronological order for the two BAs. Second, we conducted the CUSUM analysis separately for each BA to calculate the corresponding CUSUM values for operative time. Then, a learning curve was generated to illustrate the progress of skill acquisition through a fitting analysis of the CUSUM values. Determine the cut-off point that separates the learning phase from the master phase based on the slope of the curve which changes from positive to negative.

Formula of CUSUM value calculation (Equation (1)):

$$\text{CUCUM value} = \sum_{i=1}^{n} (\text{Xi-u}) \tag{1}$$

In this formula, Xi represents the operative time for each independent case, and u represents the mean operative time.

2.6. Statistical analysis

In the previous study [11], the non-inferiority margin was set at 7.5 %, we set the non-inferiority margin defined as the rate of operative complication at 2 % with a one-sided level of significance(α) of 5 % and power (1-β) of 80 %. To achieve this, the study needed to observe 91 cases. To ensure the stability of the learning curve and the accuracy of the data, we expanded the sample size to 120 cases. Statistical analysis was performed to investigate these parameters of the same phase for different BAs and the same BA for distinct phases. The normality of continuous variables was assessed using the Kolmogorov-Smirnov test. Continuous variables were compared using independent samples *t*-test or Mann-Whitney *U* test, and the data was presented in the form of median (IQR 25–75) or mean ± standard deviation according to the normality. Categorical variables were compared using the chi-square test or Fisher's exact test. All statistical analyses were performed using IBM SPSS version 22.0 (SPSS Inc, Chicago, IL, USA). A p-value <0.05, or a corrected p-value <0.05, is considered statistically significant.

3. Results

3.1. Patients characteristics

A total of 120 patients with early-stage cervical cancer were included in our study, with 41 cases in the research group (BA 1) and 79 cases in the control group (BA 2). Both groups consisted mainly of middle-aged and elderly patients, with an average age of approximately 50 years old [50.37 ± 10.19 years VS 50.53 ± 10.58 years, p = 0.975]. The majority of cases in both groups were HPV-related cervical cancer (83.33 % , 100/120), IB 1 stage (46.67 % , 56/120) and squamous cell carcinoma (74.17 % , 89/120). Most cases showed intermediate to low differentiation. No statistically significant differences were observed between the two groups in terms of general characteristics such as BMI [23.22 ± 3.49 kg/m2 VS 23.00 ± 2.87 kg/m2], parity [2 (1–3) VS 2 (2–3)], and history of previous abdominopelvic surgeries [29.3 % VS 30.4 %] (p > 0.05) (Table 1).

3.2. Learning curve

The study conducted a CUSUM analysis to obtain the learning curves of two BAs in RALH. The learning curves were divided into two phases, the first learning phase and the second master phase, based on a cut-off point where the slope of the learning curve reached zero. After comparing the learning curves of the two BAs, it was observed that BA 2, who had relatively more work experience, entered the master phase after working on 25 cases (Fig. 3A). On the other hand, BA 1 who had relatively less work experience, entered the master phase after working on 9 cases (Fig. 3B).

3.3. Comparison of surgical parameters

In terms of different work experience, when comparing the surgical parameters of BA 1 with BA 2, we found that the average operative time was extended by around 29 min (Table 1). More specifically, both in the learning phase [222 min VS 192 min, P = 0.002] and the master phase [202 min VS 174 min, P < 0.001], a significant extension of operative time was shown in the BA 1 group compared with the BA 2 group (Table 2). However, the mean operative time of both groups did not exceed 240 min. In terms of operative complications, the BA 1 group had 10 cases of infection-related complications, while the BA 2 group had 21 cases of infection-related complications and 2 cases of urinary system injury. It was observed that the incidence of operative complications in

Table 1
Compare parameters between BA 1 and BA 2.

	research group	control group	Z/X2	p value
	BA 1	BA 2		
age (years)	50.37 ± 10.19	50.53 ± 10.58	0.082	0.975[a]
BMI (kg/m2)	23.22 ± 3.49	23.00 ± 2.87	0.361	0.354[a]
Parity	2 (1–3)	2 (2–3)	0.020	0.984[b]
surgery history				
yes	12 (29.3 %)	24 (30.4 %)	0.016	0.900[c]
no	29 (70.7 %)	55 (69.6 %)		
HPV				
Yes	36 (87.8 %)	64 (81.0 %)	1.006	0.736[d]
No	1 (2.4 %)	2 (2.5 %)		
NA	4 (9.8 %)	13 (16.5 %)		
Stage				
IA	5 (12.2 %)	5 (6.3 %)	3.438	0.329[c]
IB1	22 (53.6 %)	34 (43.0 %)		
IB2	9 (22.0 %)	27 (34.2 %)		
IIA1	5 (12.2 %)	13 (16.5 %)		
Grade				
Low	14 (34.2 %)	26 (32.9 %)	1.438	0.487[c]
Medium	19 (46.3 %)	30 (38.0 %)		
High	8 (19.5 %)	23 (29.1 %)		
Histology				
Squamous	32 (78.1 %)	57 (72.2 %)	0.801	0.730[d]
Adenocarcinoma	8 (19.5 %)	17 (21.5 %)		
Adenosquamous carcinoma	1 (2.4 %)	5 (6.3 %)		
lymph node count	19 (13–25.5)	15 (11–20)	1.629	0.103[b]
operative time (minutes)	204 (195–225.5)	175 (160–200)	5.155	< 0.001[b]
length of hospital stay (days)	4 (3.5–5)	5 (4–5)	2.621	0.009[b]
positive resection margin	2 (4.9 %)	6 (7.6 %)	0.320	0.714[e]
intraoperative organ damage	0	2 (2.5 %)	1.056	0.546[e]
operative complication	10 (24.4 %)	23 (29.1 %)	0.302	0.583[c]

Table 1. The superscript of data represent the different statistical methods selected, a for *t*-test,b for Mann-Whitney *U* test,c for Chi-square test, d for Fisher's exact test and e for continuous corrected chi-square test. The data was presented in the form of median(IQR 25–75),mean ± standard deviation, or percentage(%). NA means not available data.

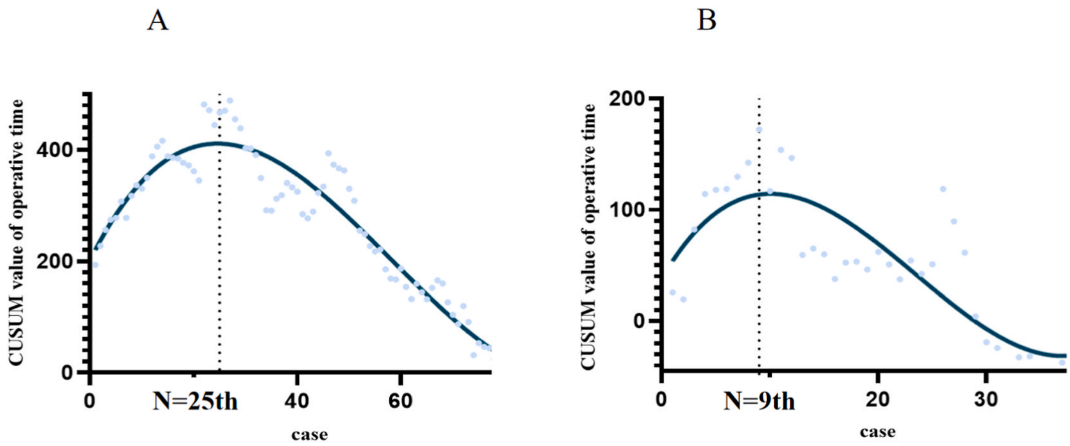

Fig. 3. These learning curve of each BA were drawn by fitting analysis of cumulative summation in terms of operative time which was recorded from the earliest one to the last one in chronological order, respectively.Vertical coordinate, namely Cusum value, is cumulative summation of each operative times minus the average operative time. Horizontal coordinate is the case order. These learning curve based on the slope were divided into two phase, the first learning phase and the second master phase. Fig. 3A is the learning curve of BA 2. Fig. 3B is the learning curve of BA 1.

Table 2
Compare operative parameters in the same phase of learning curve between BA1 and BA2.

	Learning phase				Master phase			
	BA 1	BA 2	Z/X2	P value	BA 1	BA 2	Z/X2	P value
lymph node count	15 (12.5–18.5)	15 (11–20)	0.059	0.953^{b}	19.5 (12.5–27.75)	14.5 (10.5–20.25)	1.829	0.067^{b}
operative time (minutes)	222 (211.5–240)	192 (172.5–210.5)	3.104	0.002^{b}	202 (187.75–222.5)	174 (158.5–189.25)	4.714	≤0.001^{b}
length of hospital stay (days)	5 (3.5–5.5)	5 (4–5)	0.575	0.565^{b}	4 (3.25–5)	5 (4–6)	3.091	0.002^{b}
positive resection margin	0	1 (4.0 %)	0.371	0.735^{e}	2 (6.3 %)	5 (9.3 %)	0.243	0.479^{e}
intraoperative organ damage	0	1 (4.0 %)	0.371	0.735^{e}	0	1 (1.9 %)	0.6	0.628^{e}
operative complication	2 (22.2 %)	7 (28.0 %)	0.114	0.554^{e}	8 (25.0 %)	16 (29.6 %)	0.214	0.644^{c}

Table 2. The superscript of data represent the different statistical methods selected, b for Mann-Whitney test,c for Chi-square test and e for continuous corrected chi-square test. The data was presented in the form of median(IQR 25–75) or percentage(0 %).

the BA 1 group [24.4 %, 10/41] was even slightly lower than that in the BA 2 group [29.1 %, 23/79], but the distinction was not statistically significant (P = 0.583) (Table 1). The inexperienced BA 1 group seemed not to be inferior to the experienced BA 2 group concerning positive resection margin [4.9 % VS 7.6 %, P = 0.714], number of lymph node dissections [19 VS 15, P = 0.103], and intraoperative organ damage [0 % VS 2.5 %, P = 0.546](Table 1). At the same time, even during the inexperienced learning phase, there was no statistically significant difference in the above parameters comparing BA 1 with BA 2(P > 0.05) (Table 2). After analyzing the learning curve based on the same BA (Table 3), we found that in both the inexperienced BA 1 group [222 min VS 202 min, P = 0.01]

Table 3
Compare operative parameters in different phases of learning curve for the same BA.

	BA 1				BA 2			
	Learning phase	Master phase	Z/X2	p value	Learning phase	Master phase	Z/X2	p value
lymph node count	15 (12.5–18.5)	19.5 (12.5–27.75)	1.404	0.16^{b}	15 (11–20)	14.5 (10.5–20.25)	0.190	0.849^{b}
operative time (minutes)	222 (211.5–240)	202 (187.75–222.5)	2.537	0.011^{b}	192 (172.5–210.5)	174 (158.5–189.25)	2.847	0.004^{b}
length of hospital stay (days)	5 (3.5–5.5)	4 (3.25–5)	1.427	0.174^{b}	5 (4–5)	5 (4–6)	1.353	0.176^{b}
positive resection margin	0	2 (6.3 %)	0.591	0.605^{e}	1 (4.0 %)	5 (9.3 %)	0.673	0.659^{e}
intraoperative organ damage	0	0			1 (4.0 %)	1 (1.9 %)	0.320	0.536^{e}
Operative complication	2 (22.2 %)	8 (25 %)	0.029	0.620^{e}	7 (28.0 %)	16 (29.6 %)	0.022	0.882^{c}

Table 3. The superscript of data represent the different statistical methods selected, b for Mann-Whitney test,c for Chi-square test and e for continuous corrected chi-square test. The data was presented in the form of median(IQR 25–75) or percentage(0 %).

and the experienced BA 2 group [192 min VS 174 min, P = 0.004], the operative time required during the learning phase was longer than the master phase, and the difference was statistically significant. Interestingly, except for operative time, there was no significant difference comparing the learning phase with the master phase in both groups, including length of hospital stays, positive resection margin, operative complication, and number of lymph node dissections (P < 0.05) (Table 3).

3.4. Comparison of indicators closely associated with prolonged operative time

According to current research, the operative time a minimally invasive surgery takes is closely linked to complications, such as infection and venous thrombosis. These infections can be either surgical site infections or systemic/local infections [25,26]. In our study, we found that the adverse events concluded infection. Since there is a significant difference in operative time among BAs at different phases of the learning curve or with varying levels of experience, we further analyzed whether there were differences in infectious-related operative complications among these groups (Table 4). Despite a longer operative time of approximately 29 min in BA1 compared to BA2, we found that there was no increase in the incidence of infectious-related operative complications (24.4 % vs. 26.6 %, P = 0.795). Moreover, during the learning phase, regardless of whether it was BA1 or BA2, although the operative time was significantly prolonged compared to the master phase, there was similarly no difference in infectious-related operative complications ($P > 0.05$).

4. Discussion

In a minimally invasive radical hysterectomy, to ensure better surgical and oncologic outcomes, the CS prefers to select an experienced BA to participate in this surgery. Undoubtedly, it can also limit the opportunities for young surgeons to grow and gain experience. With the FDA's approval of the da Vinci Surgical System in 2000, many specialist believe that this technique of robotic-assisted laparoscopy has reduced the dependence of the CS on BAs and mitigated the impact of BAs on the safety and efficacy of surgical outcomes due to the stability of the robotic arms in exposing surrounding tissues and the clear surgical sight. While based on current research, the conclusion seems to remain controversial. Regarding robotic-assisted prostatectomy, a study in 2018 involving 106 cases indicated that BA experience had no impact on operative time, intraoperative bleeding, postoperative complications, and hospital stays [23]. Another retrospective analysis of a small sample including 36 cases also carried out a similar conclusion concerning positive resection margin [27]. On the contrary, another retrospective analysis of a large sample showed that formally trained BA prominently improved intraoperative bleeding and positive resection margin, but this study did not define the surgical experience of BA [28]. As far as robotic-assisted nephrectomy, research has shown that the experience of BA had no significant influence on operative time, positive resection margin, and complications [29]. Whereas, for robotic-assisted hysterectomy, an increase in surgical complication and conversion rate had been presented in the inexperienced BA group compared with the skilled BA group [30].

In this study, we found that BA with less than five years of experience did indeed lengthen the average operative time by approximately 29 min in line with a large retrospective study of 2,219 surgeries including prostatectomy, hysterectomy, and inguinal hernia repair, which showed that inexperienced BA prolonged operative time around 26.9 min [31]. However, in terms of post-operative complication, positive resection margin, intraoperative organ damage, lymph node dissection count, and hospital stays, we did not find any detrimental effects in the inexperienced BA 1 group or in learning phase of the learning curve. In addition to the inherent advantages of robotic surgery itself, we speculate that the reason might be related to the modified surgical technique involving the use of the third arm instead of the uterine manipulator. Using the third arm to provide traction on the uterine horn outside the uterus offers a more flexible exposure to the surgical field as compared to using a uterine manipulator inside the uterine cavity. This allows for a stable operating space, facilitating precise tissue cutting and quick hemostasis by the CS. As a result, it reduces the CS's dependence on BA skills and minimizes the occurrence of unnecessary bleeding and tissue damage during the procedure, which contributes to decreasing the possibility of surgical complications occurring. This approach is advantageous as it enables more bedside assistants with limited experience or in the learning phase to participate in RALH surgeries.

Taking into account the longer operative time as a risk for the occurrence of postoperative infection. Therefore, we further analyzed the differences in the incidence of infection-related operative complication among BA groups with different phases of the learning curve or different experience levels. We found that despite the prolonged operative time required by BA in the learning phase or with limited experience, there was no difference in the incidence rate of infection-related complications. As to the reason, we analyze the possible reasons as follows: First, current research has found that when the duration of the operation≥240–270 min, there is a significant increase in infection-related operative complications [25,26]. While in our study, even in the BA 1 group, the average time was 204 min, and only 4 cases were more than 240 min, Therefore, we speculate that the prolonged operative time caused by the deficient experience of BA is not enough for increasing the occurrence of postoperative adverse events. Next, According to the guideling of the prevention and management of perioperative infection, during RALH, supplementary antibiotics were administered 3 h after the initial antibiotic dose has been given [32]. This measure may effectively control the occurrence of postoperative infections.

Ultimately, it is also worth noting that BA in robotic-assisted laparoscopy could be proficient after 10–36 cases [33,34], which is consistent with the number required in our research. We suppose that a BA in robotic-assisted laparoscopy has a short learning curve, even for an inexperienced BA who also could be proficient rapidly. But, there are still many shortages in this trial. First, the sample size is relatively small, and more BA should be included in future research. Second, CS is so distinguished in RALH surgery, so we do not rule out that the participation of this CS neutralizes the influence of the inexperienced BA in RALH surgery. Consequently, the comprehensive impact of BA with different levels of experience in RALH warrants additional prospective study.

Table 4
Compare infection-related complication between different BAs and different phases.

	infection-related complication		X2	P value
	YES	NO		
BA1				
Learning phase	2 (22.2 %)	7 (77.8 %)	0.029	0.62[e]
Master phase	8 (25.0 %)	24 (75.0 %)		
BA2				
Learning phase	6 (24.0 %)	19 (76.0 %)	0.125	0.724[c]
Master phase	15 (27.8 %)	39 (72.2 %)		
BA1	10 (24.4 %)	31 (75.6 %)	0.068	0.795[c]
BA2	21 (26.6 %)	58 (73.4 %)		

Table 4. The superscript of data represent the different statistical methods selected, c for Chi-square test and e for continuous corrected chi-square test. The data was presented in the form of percentage(0 %).

5. Conclusion

In robotic-assisted laparoscopic radical hysterectomy for early-stage cervical cancer, the experience and learning phase of BA only result in a slight extension of operative time, without causing worse other short-term surgical outcomes. This research expands our understanding of the impact of BA on the short-term safety and efficacy of this minimally invasive surgery.

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Ethical approval

The study was performed in line with the guidelines set forth in the Declaration of Helsinki and all the terms related to human study participants. Approval was granted by the Ethics Committee of Guangxi Medical University First Affiliated Hospital (IRB No.2023-E025-01). A informed consent was obtained from all participants.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the corresponding authors, without undue reservation.

CRediT authorship contribution statement

Hang Yu: Writing – original draft, Methodology, Formal analysis, Data curation. **Haijing He:** Methodology, Data curation. **Xuzhi Liang:** Methodology, Data curation. **Huisi Lin:** Methodology, Data curation. **Dan Sun:** Writing – review & editing, Methodology, Funding acquisition, Formal analysis, Data curation. **Jiangtao Fan:** Writing – review & editing, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

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

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