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Learning Curve on Lymph Nodes Retrieval and Postoperative Length of Hospital Stay in Robotic Rectal Cancer: A Retrospective, Observational Study

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ABSTRACT

Background and Aims: Robotic rectal cancer surgery has been introduced to reduce the difficulty and complications of the procedure. This study aims to assess the learning curve for robotic rectal cancer of individual surgeons with extensive laparoscopic rectal cancer surgery through multidimensional analyses.

Methods: Data were retrospectively collected on 156 patients who underwent robotic rectal cancer surgery by a single surgeon between January 2018 and December 2023.

Results: The operative time required for LAR can be divided into three distinct phases: an early or learning phase (1–24 cases), an intermediate or proficient phase (25–55 cases), and a late or mastery phase (56–72 cases). The study found that the learning curve for LAR and protective operative time can be divided into three distinct phases: an early or learning phase (1 to 15 cases), an intermediate or proficient phase (16 to 40 cases), and a late or mastery stage (41 to 63 cases). Following the completion of 46 cases of surgery, the next stage of the learning curve for lymph nodes retrieval has been reached. The discrepancy between the mean number of lymph nodes retrieved in each of the three stages was marginal, with an difference of 0.5 between the lowest and highest values observed (14.1 vs. 13.6 vs. 13.7). The length of hospital stay for patients decreases as the surgeon gains more experience, reaching a mean of 10.3 days in 2023.

Conclusion: This study shows that robotic surgery for rectal cancer has a significant learning curve with multiple stages. Robotic surgery can remove more lymph nodes than recommended by guidelines even during the learning phase (recommend that at least 12 lymph nodes should be retrieved). As the learning curve progresses to the mastery phase, the length of postoperative hospital stays gradually decreases to a lower level.

1 | Introduction

Rectal cancer (RC) is one of the most common cancers worldwide. Its incidence and mortality rates are reported by GLOBCAN to be the third highest in the world in 2023 [1]. Surgical removal, with or without (neo) adjuvant therapy, is the mainstay of curative treatment for rectal cancer. Minimally invasive surgery is performed to reduce postoperative pain, complications, and hospitalization time, allowing patients to quickly return to normal daily activities. While laparoscopic surgery is well-established, the role of robotic surgery in radical rectal cancer treatment is still being investigated. Robotics is believed to be capable of addressing technical limitations

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in conventional laparoscopic radical rectal cancer surgery, particularly during key surgical steps such as freeing, anastomosis, and lymph node dissection, especially for patients with high BMI [2]. The magnification of the surgical field of view by a factor of 10 during robotic surgery provides the surgeon with a better optical view. The robotic system provides control through high-definition 3D views from a surgeon-controlled camera, reducing reliance on assistant surgeons. It offers improved surgical dexterity and ergonomics, allowing for optimal manoeuvring in tight spaces. Several papers have reported potential advantages of robotics over laparoscopic surgery [3–8]. Most studies have demonstrated that robotic surgery produces clinical outcomes comparable to those of laparoscopic surgery. This includes a reduced incidence of postoperative complications, faster recovery time for postoperative bowel function, and a short-term prognosis that is no weaker than that of laparoscopic surgery [7, 9, 10].

The term "learning curve" was first used in 1909 by Bryan and Harter, and the surgical learning curve is the time and number of cases an average surgeon takes to attain surgical proficiency [11]. A study has indicated that the surgical time for robotic rectal cancer surgery is significantly longer than that of laparoscopic surgery [12]. However, a study on low rectal cancer found no significant difference in surgical time between the two surgical methods [8, 13]. It has been demonstrated that for surgeons with a high level of expertise and for medical centres with substantial experience in this field, robot-assisted surgery can be completed with a similar or reduced duration when compared with laparoscopic surgery [7]. Some reported literature suggests that robot-assisted surgery, has a faster surgeon learning curve compared to conventional laparoscopic surgery [11, 14]. Melich et al. found that after 41 robotic colorectal cases, the learning curve declined rapidly, and that robotic surgery was faster than laparoscopic surgery [14]. Yao et al. argued that surgeons performing robotic colorectal surgeries would have better outcomes, with less blood loss and shorter operative times [8]. While some authors have suggested that robotic-assisted surgery for rectal cancer has better performance in terms of operative time and postoperative complications, it is important to investigate lymph node access, which remains the most crucial factor. To our knowledge, no published studies have examined the impact of learning curve on lymph node retrieval in robotic rectal cancer, as well as on postoperative hospital stay, particularly when multiple surgical approaches are used for rectal cancer. In this study, we collected and analysed clinicopathological data from patients who underwent robotic surgery at our institution and had a diagnosis of rectal cancer. The aim was to investigate the learning curve of robotic surgery for rectal cancer and its effect on lymph node retrieval and postoperative length of hospital stay.

2 | Methods

2.1 | Study Design and Data Collection

Between January 2018 and December 2023, 156 patients with rectal cancer who underwent robotic surgery were included in Jinling Hospital of Medical School of Nanjing University. Patients were presented with the advantages and disadvantages of robotic surgery and other approaches, after which they were able to decide on a surgical procedure of their preference. Written informed consent was obtained from all participants enrolled in this retrospective study, which had been approved by the Ethics Committee of Jinling Hospital of Medical School of Nanjing University.

We collected data on these patients and retrospectively analysed it through the HIS system to obtain information on their clinical characteristics, intraoperative details, and pathological findings, which were then inserted into a maintained database. The pathological staging of tumors was assessed using the American Joint Committee on Cancer 8th edition. The methodological quality of this study was assessed by STROBE checklist [15].

Enrolled patients had to meet the following criteria: (1) pathologically confirmed rectal cancer; (2) undergoing robotic surgery at our institution; (3) patient consent to the appropriate surgical procedure.

Patients who meet these criteria were excluded. (1) 0-stage of the disease; (2) Rectal cancer that has recurred or spread; (3) Chemotherapy and/or radiotherapy before surgery; (4) Endoscopic submucosal dissection or endoscopic mucosal resection before surgery; (5) Surgery involving the removal of multiple organs, palliative surgery, or emergency surgery; (6) Incomplete medical records.

2.2 | Surgical Procedures

The surgical procedures were conducted using the Da Vinci surgical robotic system by a single senior surgeon, a highly skilled surgeon with extensive experience in laparoscopic gastrointestinal surgery. The surgeon has performed approximately 3000 laparoscopic surgeries. Feng received the Da Vinci System training certificate in 2018 (Supporting Information S1: Figure S1). The robotic surgical procedure was performed using the Da Vinci surgical system, in accordance with the expert consensus on robotic surgery for rectal cancer and was consistent with total mesorectal resection. The surgical approach employed varied between a herringbone position, a truncated position, and a modified truncated position. All patients underwent the procedure under general anaesthesia, with the use of five trocars. The principal stages of the procedure included ligation of the inferior mesenteric vascular origin and clearance of lymph nodes, freeing of the sigmoid colon and rectum, and dissociation of the rectum, if necessary, in addition to the splenic flexure (Supporting Information S1: Figure S2). Once the specimen had been completely dissected, it was extracted from the abdominal incision and then anastomosed. The surgical approach dictated whether a protective ileostomy or a permanent sigmoidostomy was performed. Finally, a pelvic drain was placed behind the anastomosis for each patient.

2.3 | Statistical Analysis

Continuous variables were presented as mean standard deviation and range, count data were expressed as frequency and percentage, normally distributed measures were expressed as mean ± standard deviation, non-normally distributed measures were expressed as median, two groups of normally distributed measures were analyzed by repeated-measures analysis of variance (ANOVA), and non-normally distributed measures were tested by non-parametric test.

The cumulative sum method (CUSUM) is powerful and valuable in the early detection of trends in data [16]. We use the CUSUM plots for analysing the robotic. Learning curve according to the operative time. The slope of the CUSUM curve represents the trend of learning outcomes, and the regime where the slope is stabilized is regarded as the phase where the surgeon demonstrates proficiency. A polynomial regression analysis was performed to fit the number of lymph nodes removed during the succession. Polynomial regression describes a pattern in data that breaks from a straight linear trend. We choose the best polynomial fit based on R^2 and methicillin resistant staphylococcus epidermodis values.

Statistical analysis was performed using IBM SPSS statistical software (Windows version 25). All tests were two-sided and p values of < 0.05 were considered statistically significant. This study has been reported in line with the guidelines [17, 18].

$$\text{CUSUMOPtime} = \sum_{i=1}^{n} (xi - \mu)$$

3 | Results

3.1 | Demographic, Pathological Findings and Operative Outcomes of Patients

The study included 156 consecutive patients who underwent robotic rectal surgeries (Figure 1). The proportion of men was about 66.7%. 55.1% of patients had other comorbidities. The ASA classification indicates that 55.1% of patients exhibited Grade 2 or higher. There were no intraoperative complications, no cases of conversion, and no mortality. Seventy-two patients underwent low anterior resection (LAR), 63 patients underwent LAR and protective ileostomy and 21 patients underwent abdominoperineal resection (APR). Mean operative time was 262.0, 267.0, 295.5 (mins), mean number of lymph nodes retrieved was 13.9, 14.1, 12.5. Mean postoperative length of hospital stay (days) was 14.3, 11.8, 10.1, respectively. The pathological results indicated that Stage II + III, and poorly to moderate differentiation were the most prevalent in the cohort, with the percentage of T3 + T4 and N0 stages exceeding 50%. Detailed are shown in Table 1.

3.2 | Learning Curve on Operative Time and Lymph Nodes Retrieval

We used CUSUM analysis and the learning curve of LAR operative time could be divided into three distinct phases: early or learning phase (1 to 24 cases), intermediate or proficient phase (25 to 55 cases) and late or mastery phase (56 to 72 cases) (Figure 2). The mean operative time was 284 min (SD ± 48.1, range 220–380) for the learning phase, 259 min (SD ± 44.6, range 185–325) for the proficient phase and 237 min (SD ± 24.5, range 200–280) for the mastery phase. A significant decrease in mean operative time was observed between the learning, proficiency and mastery phases ($p = 0.007$ Figure 3). The learning curve of LAR and protective ileostomy for operative time could be divided into three distinct phases, the early or learning phase (1 to 15

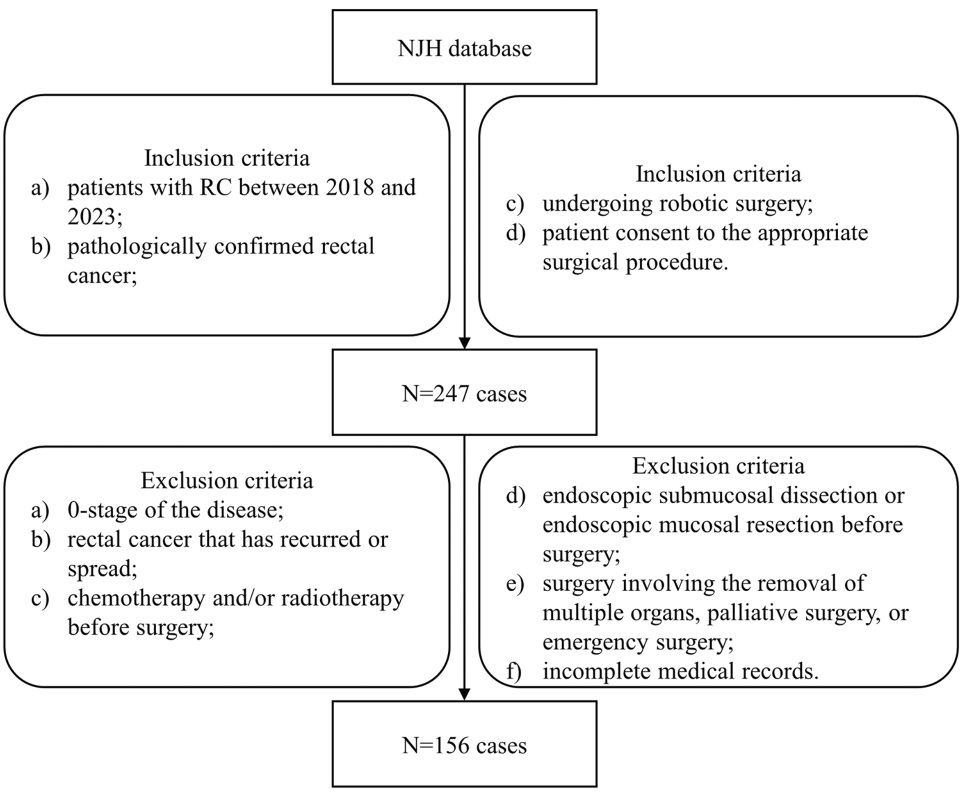

FIGURE 1 | Flow diagram of robotic RC patients from NJH database. NJH, Nanjing Jinling Hospital; RC, rectal cancer.

TABLE 1 | Demographic, pathological findings and operative outcomes of patients.

Variables	LAR ($n = 72$)	LAR + protective ileostomy ($n = 63$)	APR ($n = 21$)
Age (years)	61.8 ± 8.4	61.4 ± 11.9	62.6 ± 8.7
Gender			
Male	50 (69.44%)	43 (68.25%)	11 (52.38%)
Female	22 (30.56%)	20 (31.75%)	10 (47.62%)
Body mass index (kg/m^2)	25.91 ± 2.33	20.02 ± 2.19	21.41 ± 2.17
Tumor location[a]	10.4 ± 3.9	6.9 ± 3.5	4.4 ± 2.0
Comorbidity	44 (61.11%)	32 (50.79%)	10 (47.62%)
Cardiovascular disease	8 (11.11%)	6 (9.52%)	0 (0)
Diabetes	10 (13.89%)	6 (9.52%)	7 (33.33%)
ASA grading≥ 2	44 (61.11%)	32(50.79%)	10 (47.62%)
Previous abdominal surgery (%)	11 (15.28%)	21 (33.33%)	5 (23.81%)
Intraoperative complication (%)	0 (0)	0 (0)	0 (0)
Conversion (%)	0 (0)	0 (0)	0 (0)
Mortality (%)	0 (0)	0 (0)	0 (0)
Tumor size (cm, mean ± SD)	3.9 ± 1.5	3.6 ± 1.3	4.3 ± 1.6
Grade			
Well	3 (4.17%)	2 (3.17%)	0 (0)
Moderate	51 (70.83%)	37 (58.73%)	10 (47.62%)
Poor	18 (25.00%)	24 (38.10%)	11 (52.38%)
pTNM Stage			
I	12 (16.67%)	17 (26.98%)	7 (33.33%)
II	27 (37.50%)	20 (31.75%)	9 (42.86%)
III	33 (45.83%)	26 (41.27%)	5 (23.81%)
T stage			
T1	11 (15.28%)	10 (15.87%)	4 (19.05%)
T2	9 (12.50%)	19 (30.16%)	3 (14.29%)
T3	46 (63.89%)	29 (46.03%)	11 (52.38%)
T4	6 (8.33%)	5 (7.94%)	3 (14.29%)
N stage			
N0	39 (54.17%)	37 (58.73%)	16 (76.19%)
N1	22 (30.56%)	15 (23.81%)	0 (0)
N2	11 (15.28%)	11 (17.46%)	5 (23.81%)
No. of lymph nodes retrieval (mean ± SD)	13.9 ± 4.1	14.1 ± 4.2	12.5 ± 4.0
Operation time (min, mean ± SD)	262.0 ± 45.2	267.0 ± 62.7	295.5 ± 45.8
Estimated blood loss (mL, mean ± SD)	121.0 ± 133.3	120.5 ± 114.5	154.8 ± 193.6
Length of stay (days) after surgery (mean ± SD)	14.3 ± 12.2	11.8 ± 10.6	10.1 ± 6.1

Abbreviations: APR, abdominoperineal resection; ASA, American Society of Anesthesiologist Acore; LAR, low anterior resection.
[a]Indicate distance from tumor lower margin to the anal verge, cm.

cases), the intermediate or proficient phase (16 to 40 cases) and the late or mastery phase (41 to 63 cases) (Figure 2). The mean operative time was 312 min (SD ± 62.4, range 224–395) in the learning phase, 266 min (SD ± 60.5, range 180–396) in the proficient phase and 238 min (SD ± 48.8, range 180–360) in the mastery phase. A significant reduction in mean operative time between the learning, proficiency and mastery phases was also observed ($p = 0.001$, Figure 3). The learning curve of APR for operative time continued to fluctuate and did not reach a stable level (Figure 2).

We used a third-degree polynomial function to analyse the effect of the learning curve on the number of lymph nodes retrieval during robotic rectal cancer. A progressive increase in the number of lymph nodes retrieved was observed up to case 46, after which the proficient stage was reached. This was

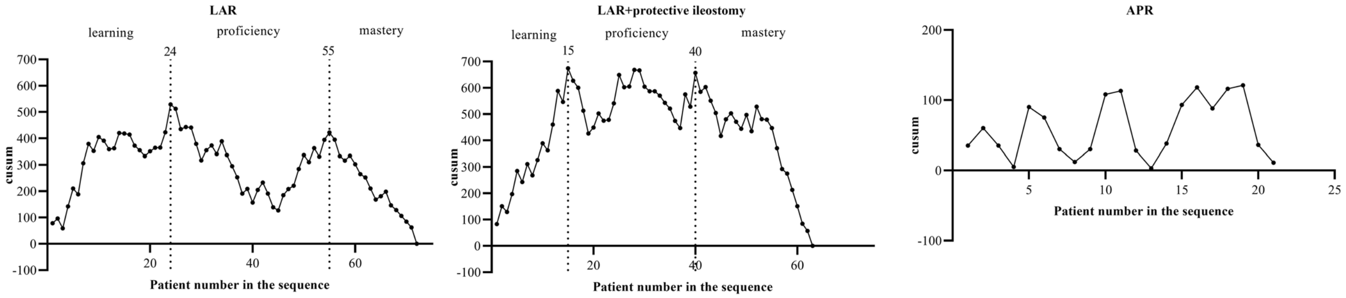

FIGURE 2 | Cumulative sum method (CUSUM) analysis for robotic rectal cancer. The vertical line located in the turning point of curvature indicates the point at which a surgeon transitions from one phase to another.

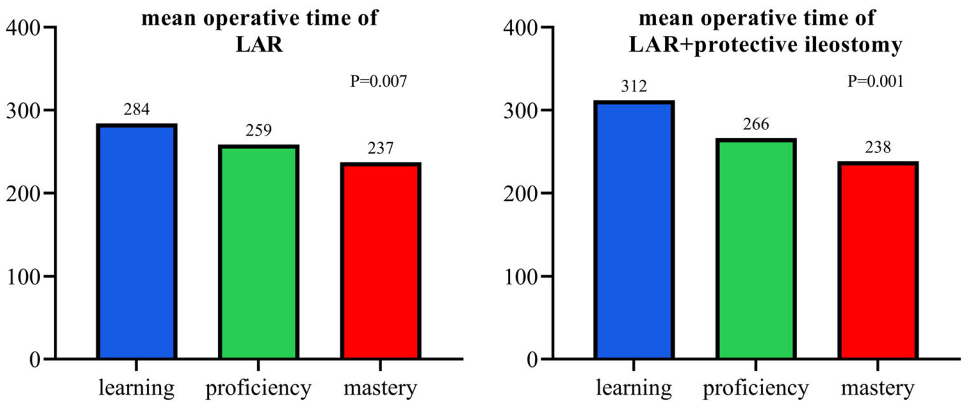

FIGURE 3 | Mean robotic rectal cancer operative time (minutes) in the learning, proficiency and mastery phases.

followed by the mastery stage after 119 cases. The mean number of lymph nodes retrieved in the learning phase was 14.1 (SD ± 4.8, range 8–25), while the mean number of lymph nodes retrieved in the proficient phase was 13.6 (SD ± 3.9, range 8–23), and in the mastery phase it was 13.7 (SD ± 3.6, range 9–23) (Figure 4).

3.3 | Learning Curve on Postoperative Length of Hospital Stay

As robotic surgery for rectal cancer progresses from the learning phase to the proficient phase and mastery phase, figure shows the postoperative length of hospital stay by year for 156 patients (Figure 5). The year with the longest postoperative hospital stay was 2021, with an average of 16.5 days. Since then, the length of hospital stays after surgery has been consistently decreasing. In 2021, a patient who underwent LAR surgery developed an anastomotic fistula and dysuria on postoperative Day 6, the patient's anastomotic fistula gradually healed after abdominal irrigation and drainage and medication to control the infection. The patient was discharged from the hospital with resumption of transoral feeding and was hospitalised for 49 days postoperatively. Another patient who underwent LAR surgery developed anastomotic leakage on the day 8 after surgery, and gradually healed after the abdominal irrigation and drainage and infection control drug treatment. The patient returned to oral feeding at discharge and was hospitalized for 47 days. The shortest postoperative hospital stay was 2023 with an average of 10.3 days.

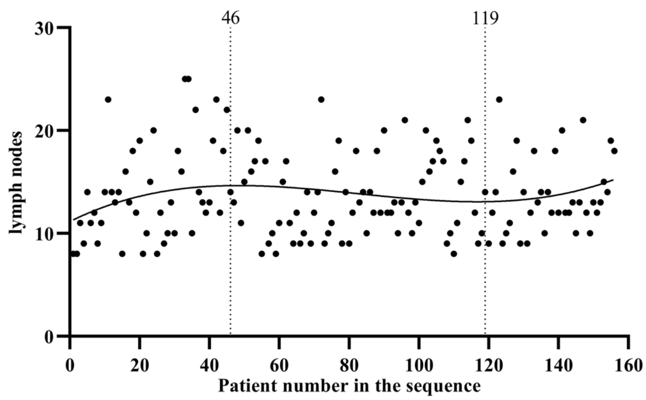

FIGURE 4 | A third-degree polynomial function of lymph nodes retrieval after robotic rectal cancer. The vertical line situated at the turning point of the curve indicates the point at which the surgeon achieves enhanced proficiency in the retrieval of lymph nodes.

4 | Discussions

Rectal cancer surgery is still considered a technically challenging procedure. The technical threshold for performing adequate lymph node dissection remains high, with a steep learning curve. This study shows that robotic surgery for rectal cancer has a significant learning curve with multiple stages. Robotic surgery can remove more lymph nodes than recommended by guidelines even during the learning phase (recommend that at least 12 lymph nodes should be retrieved in rectal cancer) [19]. Robotic platforms provide several

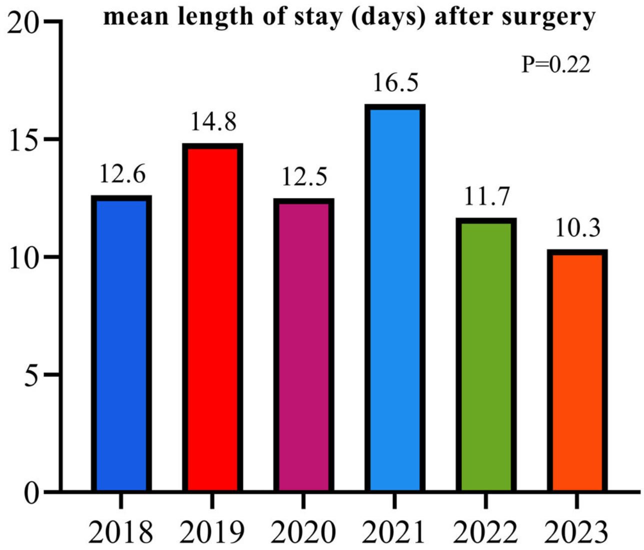

FIGURE 5 | Mean robotic rectal cancer length of stay (days) after surgery in 2018–2023.

technological advantages over laparoscopic surgery. These include improved dexterity, increased range of motion of the instrument tips, enhanced ergonomics, elimination of physiological tremor, improved 3D vision, and a better surgical field of view. Robotic systems offer even more significant advantages for surgery in confined spaces, such as the pelvis [20]. For low and intermediate rectal cancers, robotic surgery provides comparable short-term oncological outcomes and superior anal function when compared to laparoscopic surgery [9]. Robot-assisted radical rectal cancer procedures carried out in experienced laparoscopic surgery centres can lead to shorter operative and hospital stays, as well as fewer complications, compared to laparoscopic surgery [21]. Crain found no significant difference in 30-day readmission or mortality rates between patients undergoing robotic surgery and those undergoing laparoscopic surgery [6]. A study analysed the clinical history of 62 patients who underwent robotic-assisted rectal cancer surgery. The study found that robotic-assisted surgery was safe and technically feasible for rectal cancer [22], with a good short- and long-term prognosis. Additionally, after propensity-matched analysis, 100 robotic and 100 laparoscopic surgeries demonstrated similar outcomes in terms of perioperative and disease-free survival in radical rectal cancer surgery [7]. Patients with rectal cancer who have received neoadjuvant therapy and undergo robotic-assisted surgery have a good short-term prognosis [23]. Robotic surgery, with the operator seated, allows for greater ease in freeing vital organs and precise lymph node dissection. This quickly overcomes the corresponding learning curve.

According to the literature, the learning curve for robot-assisted rectal surgery is consistent across all categories of rectal cancer surgical procedures [24–26]. Studies utilizing the CUSUM method have demonstrated that a minimum of 10–44 cases are required [26]. Sugishita et al. assessed of the robotic total mesorectal excision (TME) learning curve in terms of surgical time has identified three distinct phases: the learning phase (cases 1–32), the proficiency phase (cases 33–54), and the mastery phase (cases 55–63) [26]. According to Olthof et al. [21], the use of the CUSUM method to observe the learning curve of 100 robotic rectal cancer surgeries resulted in a significant reduction in operative time after the first 40 cases, indicating progression to the next phase. According to a review, a surgeon needs an average of 39 cases to be considered an expert in robotic surgery. Melich et al. [14] demonstrated that after the initial 41 cases, there was a rapid reduction in robotic surgical time, which was faster to learn than laparoscopic surgery. Choi et al. found that robotic-assisted rectal cancer surgery could even improve surgical time [27].

Our results are similar to those reported by Choi, Sugishita et al. [26, 27]. The CUSUM analysis of the learning curve for LAR surgery or surgery with LAR combined with protective ileostomy allowed the identification of three distinct phases, as shown in Figure 2. The early stage represents the learning phase, as indicated by the folded line with a positive slope, which most likely involves adaptation to the cases required for the robot. During the proficiency phase, a second peak in operating time was identified, which may have been caused by technical difficulties encountered during the operation. For instance, the procedure is complicated by a considerable amount of bleeding during the operation, or the tumor is too large and difficult to expose, and the adhesion between the tumor and the bladder is tight. Once the operator has surpassed the proficiency level in terms of their ability to handle complex case, they enter the mastery phase. The analysis of the learning curve of operative time in the APR group demonstrated continuous fluctuations but did not reach a plateau. The operative time and intraoperative haemorrhage in the APR cohort were significantly longer than in the other two cohorts. However, due to the small number of patients in this group, definitive conclusions cannot be drawn.

Lymph node dissection is a critical step in rectal cancer surgery. Studies have shown that the accuracy of pathological staging improves when an adequate number of lymph nodes are removed. Guidelines recommend the dissection of at least 12 lymph nodes for rectal cancer [28]. A recent analysis by Olthof et al. of 100 patients showed that the mean number of lymph nodes removed after robotic radical rectal cancer surgery was significantly higher compared to laparoscopic surgery [21]. The median number of lymph nodes retrieval was 13 (range 11–17) in the robotic group and 12 (range 10–16) in the laparoscopic group ($p = 0.006$). We found that during the learning phase of robotic rectal cancer surgery in our study, the mean lymph node retrieval was 14.1, which is higher than the guideline recommendations (12). The discrepancy between the mean number of lymph nodes retrieved in each of the three stages was marginal, with an difference of 0.5 between the lowest and highest values observed (14.1 vs. 13.6 vs. 13.7). We also found that the mean postoperative length of hospital stay for the all cohort tended to decrease over time. It has been demonstrated that the length of hospital stay decreases as surgeon experience increases in patients undergoing robotic-assisted hernia [29]. In our study, a cohort of 156 robotic rectal cancer surgeries, the average postoperative length of stay was 12.6 days in 2018, peaking at 16.5 days in 2021. The mean postoperative length of stay gradually decreased in subsequent years, reaching a mean of 10.3 days in 2023. It seems plausible to suggest that enhanced levels of surgeon confidence may be responsible for a concomitant increase in the number of complex surgical cases requiring treatment, resulting in longer postoperative stays. For example, in the 2021 cohort, a number of patients had a history of major abdominal surgery. With increasing surgical experience, there was a gradual reduction in postoperative days.

This study presents an analysis of the learning curve for robotic surgery for rectal cancer, with a focus on the number of lymph nodes retrieval and the length of postoperative hospital stay. All cases were performed by the same operator. The operator achieved proficiency in lymph node retrieved after 46 cases, this was followed by the mastery stage after 119 cases. The mean number of lymph nodes acquired in the learning phase (14.1) was higher than that in the subsequent phases (13.6 and 13.7), both of which exceeded the guideline recommendations (12). The learning curve for lymph nodes retrieval, with a turning point of 46 cases, was greater than the 24 or 15 cases required in the learning phase of the learning curve for the operative time, suggesting that the oncological adequacy of the procedure was not compromised during the learning phase of robotic rectal cancer. It was also observed that as surgeon experience increased, there was a gradual and consistent decrease in the average length of hospital stay for patients undergoing robotic surgery for rectal cancer. This suggests that robotic rectal cancer surgery may offer some advantages in short-term outcomes as surgeon experience increases.

This study is further limited by the typical defects inherent in single-centre, retrospective research. Despite the plethora of research reports on robotic surgery, accurate comparison and measurement of the surgical experience of doctors in different countries and institutions remains challenging. At the initial learning curve stage, the surgeon must gradually adapt to the robot's operation mode, potentially requiring novice doctors to allocate more time to adapting to the operation space. For instance, surgeons lacking experience in the learning curve may encounter difficulties in situating multiple mechanical arms within their field of vision, as the imaging system of the robot is characterised by its enlargement. The patients included in this study were all operated on by a surgeon with extensive expertise in laparoscopic surgery. (It should be noted that our unit, being a teaching hospital and a regional centre specialising in the diagnosis and treatment of colorectal diseases, has treated a considerable number of patients requiring laparoscopic assisted colorectal disease surgery, and only surgeons with considerable seniority and extensive experience in laparoscopic surgery are entrusted with performing robotic surgery in our centre, this is to mitigate the potential risk to the survival benefits of rectal cancer patients) [30–32]. The study revealed that, irrespective of the surgical approach (LAR or LAR and protective ileostomy), the learning curve can be entered at a level of proficiency after a smaller number of cases. This finding suggests that the surgeon's prior experience with laparoscopic surgery may facilitate the transition to more advanced stages of the learning curve in robot-assisted surgery. Secondly, the core members of our medical team have been collaborating for a period of 9 years. It is hypothesised that the experience of the first assistant and the tacit cooperation with the chief surgeon can significantly improve the operation efficiency and shorten the operation time, which is very important for the chief surgeon to cross the learning curve. The precise placement of robot equipment and the scientific adjustment of patient position are also key links for the success of surgery. The first assistant must possess a comprehensive understanding of the specific requirements of the surgery, including the configuration of the robotic apparatus and the optimal positioning of the patient, to ensure the maximal exposure of the surgical field of vision. In addition to these competencies, the first assistant must also be proficient in the utilisation and replacement of surgical instruments, as well as the management of intraoperative emergencies. These factors have the potential to influence the operation time and the acquisition of lymph nodes. Thirdly, in China, due to the high cost of robotic surgery and the current situation that some cities have not been included in medical insurance, the first assistant (usually served by senior doctors) needs to elaborate on the advantages, potential complications and costs of robotic surgery to patients and their families, so as to ensure that patients and their families make choices on the basis of full understanding. All the patients in this study chose the surgical method completely voluntarily. However, a correlation was identified between patients with higher economic status and better nutritional status, as indicated by their better management of underlying diseases and higher levels of medical compliance. This may have implications for postoperative hospital stay. As the da Vinci surgical robot continues to gain popularity, further validation of our results should be carried out by surgeons from other study sites, preferably those without long-term laparoscopic surgical experience. Future research should involve a multidimensional analysis of multiple indicators during robotic surgery by different centres and surgeons, including variables such as conversion rate, complications, and oncological outcomes. Additionally, a comparison of the results with the laparoscopic group was not possible due to an insufficient number of cases undergoing laparoscopic assisted rectal cancer surgery with the same inclusion and exclusion criteria, and by the same surgeon, at our centre during the same period for analysis. The selection of a limited number of cases may have introduced a risk of drawing controversial conclusions in research. The present study primarily demonstrates the feasibility of a highly experienced laparoscopic surgeon commencing robotic surgery. Higher standards of evidence will require the undertaking of multicentre studies, and studies on a larger scale.

5 | Conclusions

This study shows that robotic surgery for rectal cancer has a significant learning curve with multiple stages. Even during the learning phase, robotic surgery can result in the removal of more lymph nodes than is recommended by guidelines. As the learning curve progresses to the mastery phase, the length of postoperative hospital stays gradually decreases to a lower level.

Author Contributions

Yan Yang: conceptualization, data curation, methodology, writing – original draft. **Yao Yao:** data curation, methodology, writing – review and editing. **Xiangyang Li:** data curation, methodology, software, validation, writing – review and editing. **Ling Ni:** data curation, writing – review and editing. **Zhenning Hang:** data curation, writing – review and editing. **Xiaobo Feng:** conceptualization, formal analysis, project administration, resources, supervision, writing – review and editing.

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Ethics Statement

This study conformed to the provisions of the Declaration of Helsinki. The study received ethical approval from the Institutional Review Committee at Jinling Hospital of Medical School of Nanjing University (No.2024DZKY-110).

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

All authors have read and approved the final version of the manuscript. Xiaobo Feng had full access to all of the data in this study and takes complete responsibility for the integrity of the data and the accuracy of the data analysis. All the data could be available through the requirement for the corresponding author. For any queries, kindly contact fengboxiao@163.com.

Transparency Statement

The lead author Xiaobo Feng affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.