The learning curve of robotic radical cystectomy *vs.* open radical cystectomy

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Abstract: Robot-assisted radical cystectomy (RARC) is a minimally invasive surgical procedure that offers advantages over standard open radical cystectomy (ORC), such as shorter operation time (OT), less blood loss, and quicker recovery time. However, RARC is a technically demanding procedure with a learning curve associated with it. The learning curve depends on various factors, including OT, estimated blood loss (EBL), lymph node (LN) yield, and the number of dissected LNs. OT has been reported to decrease as surgeons gain experience, while EBL has been found to increase during the learning period. Surgical technique, patient characteristics, and surgeon expertise may contribute to this variability. LN yield tends to increase as surgeons gain experience, with studies showing that the number of dissected LNs and their yield tend to increase as surgeons gain experience. However, prospective studies are needed to determine better results or if this improves survival. Most studies have shown a decrease in length of stay (LOS) as surgeons gain experience, with some studies not observing a significant reduction in complication rates. The learning curve in RARC is pivotal in determining surgeon competence and patient outcomes. Understanding the trajectory of the learning curve and its impact on various parameters is essential for surgical training programs and the safe implementation of RARC. Key parameters such as OT, EBL, LN yield, LOS, postoperative complications, positive surgical margins (PSMs), and long-term oncological outcomes are examined to gain insights into the learning curve in RARC. Surgeons typically require approximately 9 to 50 cases to achieve proficiency in various parameters during the learning curve. However, certain intracorporeal techniques may require 130 procedures to flatten the learning curve. It is crucial to consider individual variations, surgical techniques, and institutional factors that may influence the learning curve. Standardization of study designs, statistical analysis, and surgical training programs will facilitate a better understanding of the learning curve in RARC and contribute to improved patient outcomes.

Keywords: Learning curve; open radical cystectomy (ORC); robot-assisted radical cystectomy (RARC)

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Introduction

Robot-assisted radical cystectomy (RARC) is a minimally invasive surgical procedure increasingly used to treat bladder cancer. The utilization of RARC presents numerous potential benefits compared to the conventional open radical cystectomy (ORC), including shorter operation time (OT), less blood loss, and a quicker recovery time. However, RARC is a technically demanding procedure, and a learning curve is associated with it (1).

The concept of the learning curve is commonly employed to delineate the temporal or quantitative threshold that surgeons must surpass in order to attain proficiency in a novel surgical technique (2). In the case of RARC, a less-invasive alternative to ORC, understanding the learning curve is of utmost importance to ensure safe and effective surgical practice. The research has demonstrated that RARC exhibits comparable surgical outcomes and comparable perioperative results. Additionally, the robotic technique has the added benefit of improving surgeon comfort, which includes better ergonomics, increased dexterity, improved visualization. Compared to laparoscopic and open surgery, there is less tiredness and physiological tremor in the surgeon. These elements may facilitate quicker learning (3,4).

This review aims to provide an in-depth analysis of the learning curve in RARC by examining various parameters that influence the curve and discussing the implications for surgical training and patient outcomes.

The learning curve depends on various factors

OT

OT is a key parameter in assessing the learning curve in RARC. Several studies have reported a decrease in OT as surgeons gain experience in performing the procedure. For instance, Collins *et al.* observed a reduction in OT from the first group of patients to the latter groups for two surgeons (5). Dell'Oglio and colleagues have presented evidence of a characteristic learning curve phenomenon in the context of OT, wherein a period of initial improvement is followed by a plateau phase, typically occurring after the completion of roughly 50 procedures (6). Similarly, Desai *et al.* found that overall OT did not differ significantly (7).

The influence of the type of diversion on the learning curve has been examined in only a limited number of studies. For instance, In a study undertaken by Hayn *et al.*, the duration of cystectomy was analyzed independently from other procedures (1). In another study by Porreca *et al.*, the learning curve was assessed for both the total OT and the time required for cystectomy and urinary diversion, although the specific time taken for cystectomy was not analyzed. According to the research conducted by Porreca *et al.*, it was found that the orthotopic neobladder diversion exhibited the most extended duration, followed by the ileal conduit and ureterocutaneostomy diversions. Nevertheless, the perioperative results did not exhibit any statistically significant variations across the different diversion groups (8).

Overall, the majority of studies suggest that between 9 and 50 cases are required for significant reductions in OT during the learning curve (1,5-7). However, the highly demanding intracorporeal techniques may require 130 procedures to flatten the learning curve (9).

Estimated blood loss (EBL)

The current body of research does not provide a definitive conclusion about the influence of the learning curve on EBL in RARC. While some studies have reported a decrease in EBL as surgeons gain experience, others have found no significant change. It is important to note that EBL during RARC varies across studies, ranging from 200 to 2,200 mL. Jonsson *et al.* and Guru *et al.* in their studies showed that EBL increased during the learning period (10,11). The possible reasons for this were not discussed. Factors such as surgical technique, patient characteristics, and surgeon expertise may contribute to this variability. Porreca *et al.* conducted a study that demonstrated a substantial inverse relationship between the number of cases and the EBL with a $P=0.004$ (8). The aforementioned "proficiency marker" demonstrated notable growth during the learning process. Additional investigation is required in order to comprehensively understand the correlation between the learning curve and EBL after RARC.

Lymph node (LN) yield

The quantification of dissected LNs and their resulting output is a crucial determinant in evaluating the progression of learning skills in RARC. Research findings indicate that there is a positive correlation between the expertise level of surgeons and the yield of LNs during surgical procedures. According to Hayn *et al.*, an estimated sample size of 30 patients is required in order to obtain a count of 20 LNs (1). Similarly, Tae *et al.* observed an incremental increase in

LN yield with every 40 cases (12). In the multicenter trial conducted by Hellenthal *et al.*, it was observed that patients exhibited a significantly higher likelihood of undergoing lymphadenectomy following the 20th case [95% confidence interval (CI): 2.41–10.07, P=0.001] (13). However, lymph nodal staging serves only a purpose of improved nodal staging for the patients.

Length of stay (LOS)

The duration of hospitalization, commonly referred to as LOS, is a significant factor when assessing the learning curve in RARC. Multiple studies have documented a reduction in LOS as surgeons accumulate experience. In the study conducted by Schumacher *et al.*, the LOS exhibited a drop following the initial group of 15 patients out of a total of 45 patients (12 *vs.* 8 *vs.* 8 days, P=0.006) (14). However, further studies are needed to determine whether the LOS is comparable or better.

Postoperative complications

Postoperative complications are critical indicators of surgical quality and play a significant role in evaluating the learning curve in RARC. The majority of studies have shown a decrease in postoperative complication rates as surgeons gain experience. Following the initial fifteen patients, Schumacher *et al.* saw a progressive decline in late complications (>30 days), with a statistically significant P value of 0.005 (14). However, it is worth noting that some studies did not observe a significant reduction in complication rates, possibly due to the limited number of cases analyzed. Additional investigation is required to examine the correlation between the learning curve and postoperative problems in RARC.

Positive surgical margins (PSMs)

Identifying PSMs is a crucial metric in RARC, which significantly impacts patients' prognosis. In their study, Hayn *et al.* discovered that a sample size ranging from 24 to 30 patients was necessary for surgeons to get a 5% overall PSM rate (1).

Long-term oncological outcomes

There is a scarcity of data pertaining to the correlation between the learning curve and the long-term oncological results in RARC. In their respective studies, Hayn *et al.* and Tae *et al.* conducted a comparative analysis of overall survival, recurrence-free survival, and cancer-specific survival throughout various stages of the learning curve. Their findings did not reveal any statistically significant differences (1,12). Dell'Oglio *et al.* reported lower recurrence rates after 18 months as surgeons gained experience (6).

Comparison with ORC

Peri-operative complications is an important factor in comparing open *vs.* robotic approach. RARC results in lower complication rate as determined in various studies. The RARC group may have fewer complications due to the lower EBL and minimally access technique. The lower complication rates of RARC may indicate that it is a comparable modality for older individuals with muscle-invasive bladder cancer patients with comorbidities. Phillips *et al.* recommended RARC for patients over 80 with indications for RC, and complication rates were acceptable even in patients with many comorbidities (15). According to Knox *et al.*, RARC performed better in patients over the age of 70 years even compared to ORC (16).

According to the International Robotic Cystectomy Consortium, robot-assisted LN dissection can generate LN yield similar to ORC (17).

The OT difference between ORC and RARC in a study by Xia *et al.* was less for robotic instances with more than 50 patients (18). Several of the included studies stated that as surgeon volumes increased, OT of RARC reduced. The RARC group's longer OT is due to the additional surgical steps needed to set up the trocar, dock and undock the robot, and transition to extracorporeal urine diversion. Additionally, RC is a time-consuming process in and of itself (19).

Cochetti *et al.*, in their study of 112 patients showed that mechanical stapler is an effective technique in RARC with intracorporeal ileal conduit. In a subgroup analysis they showed that mean OT and EBL improved significantly (20).

Soft tissue, urethral/ureteric, and overall nonspecific PSM rates were similar for RARC and ORC in several research. Overall PSM rates in RARC were 5.7% compared to 8.8% in ORC (13,21).

The phase 3 RAZOR study compared progression-free survival in carcinoma bladder patients who underwent RARC and ORC. They concluded that RARC had similar outcomes with lower complications. The RARC group had a 2-year progression-free survival of 72.3% (95% CI: 64.3% to 78.8%), while the ORC group had 71.6% (95% CI: −9.6% to 10.9%; non-inferiority =0.001) (22).

Cost analysis between two groups is worthy of discussion because healthcare cost reduction is one of the most important issues of our time. RARC was found to have a higher expense (+$1,640) in the perioperative environment, according to Smith *et al.* They did not, however, analyze the price of hospital medications (23). Another study found that actual overall patient expenditures showed a 38% cost advantage in favor of RARC because ORC had higher hospitalization costs and complication rates (24).

Discussion

RC is complicated and has a significant perioperative mortality rate. The learning curve of RARC affects surgeon skill and patient outcomes. Understanding the learning curve and its effects on parameters is crucial for surgical training programs and safe RARC deployment. In this comprehensive review, we have examined key parameters such as OT, EBL, LOS, postoperative complications, LN yield, positive margins, and long-term oncological outcomes to gain insights into the learning curve in RARC.

OT is a commonly studied parameter in assessing the learning curve. Our analysis revealed that the majority of studies reported a decrease in OT as surgeons gained experience in performing RARC. This reduction in OT is indicative of improved surgical efficiency and proficiency. Surgeons typically require approximately 9 to 50 cases to achieve significant reductions in OT during the learning curve (25,26). The operating time varies between studies, ranging from about 530 minutes during the initial period to ≤300 minutes near the termination of the learning curve (14,27). However, it is important to note that factors such as prior robotic experience and surgical technique may influence it.

EBL is another critical parameter in evaluating the learning in RARC. The impact of the learning curve on EBL remains inconclusive, with some studies reporting a decrease in blood loss as surgeons gain experience, while others finding no significant change. The variability in EBL across studies may be attributed to factors such as patient characteristics, surgical technique, and surgeon expertise (1,5,7).

LN yield is another important indicator of surgical quality and staging accuracy in RARC. The incremental increase in LN yield observed with each case suggests that surgeon experience positively influences this parameter. Achieving an adequate LN yield is crucial for accurate staging and determining appropriate treatment strategies. The learning curve for LN yield typically requires approximately 30 to 40 cases (28).

LOS is a parameter that reflects perioperative care and surgical efficiency. Our review demonstrates that the learning curve in RARC is associated with a decrease in LOS. Surgeons tend to achieve proficiency after a certain number of cases, resulting in shorter hospital stays for patients. This reduction in LOS signifies improved perioperative care, enhanced surgical skills, and efficient postoperative management. The learning curve for LOS typically requires around 10 to 15 cases, but it is important to consider variations in institutional practices and healthcare standards (7,10,11,29).

Postoperative complications are critical outcomes in evaluating the learning curve in RARC. The majority of studies reviewed reported a decrease in complication rates as surgeons gained experience. This finding suggests that the learning curve is associated with improved surgical techniques, decision-making, and postoperative care. However, it is worth noting that some studies did not observe a significant reduction in complication rates, possibly due to limited sample sizes or other confounding factors (6,7).

Few studies have specifically examined the learning curve for PSM in RARC. The limited data available suggest that surgeons require approximately 24 to 30 cases to achieve a lower overall PSM rate (1).

Although limited data are available, existing studies suggest that the learning curve does not significantly impact long-term survival rates, recurrence-free survival, or cancer-specific survival. This finding implies that the learning curve does not compromise the oncological efficacy of RARC (1,12).

Conclusions

This comprehensive review provides insights into the learning curve in RARC, examining key parameters such as OT, EBL, LN yield, LOS, postoperative complications, PSMs, and long-term oncological outcomes. Surgeons typically require approximately 9 to 50 cases to achieve proficiency in various parameters during the learning curve. However, it is crucial to consider individual variations, surgical techniques, and institutional factors that may influence the learning curve. Standardization of study designs, statistical analysis, and surgical training programs will facilitate a better understanding of the learning curve in RARC and contribute to improved patient outcomes.

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