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Determining the component-based operative time learning curve for robotic-assisted radical prostatectomy

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Abstract

Objectives: To determine the learning curve (LC) of total operative time and the discrete components of the robotic-assisted radical prostatectomy (RARP) for a recent robotic fellowship-trained urologic surgeon.

Materials and methods: We performed a retrospective analysis of RARP procedures performed by a single new attending surgeon from August 2015 to April 2019. Patients' demographics and operative details were assessed. Total operative time was divided and prospectively recorded in 7 parts: (*a*) docking robot, (*b*) dissecting seminal vesicles (SVs) (*c*) dissecting endopelvic fascia (EPF), (*d*) incising bladder neck (BN), (*e*) completing the dissection, (*f*) lymph node dissection, and (*g*) urethrovesical anastomosis (UVA) and robot undocking. Cumulative sum analysis was used to ascertain the LC for total operative time and the 7 parts of the procedure.

Results: One hundred twenty consecutive RARPs were performed. The LC was overcome at 25 cases for total operative time, 13 cases for docking the robot, 33 cases for dissecting SVs, 31 cases for dissecting EPF, 46 cases for incising BN, 38 cases for prostate dissection, 25 cases for lymph node dissection, and 52 cases for UVA. Total operative time was decreased 22.8% ($p < 0.0001$) and time for robot docking, dissecting SVs, dissecting EPF, incising BN, completing prostate dissection, lymph node dissection, and UVA were decreased 16.7%, 30.5%, 29.5%, 36.2%, 37.3%, 32.2%, and 26.9%, respectively (all $p < 0.05$).

Conclusions: We observed a 25-case LC for a fellowship-trained urologist to achieve stable operative performance of RARP surgery. Procedural components demonstrated variable LCs including the UVA that required upward of 52 cases.

Keywords: Cumulative sum (CUSUM) analysis; Learning curve; Prostate cancer; Robotic-assisted radical prostatectomy

1. Introduction

Prostate cancer is the most commonly diagnosed cancer in men.[1] Robotic-assisted radical prostatectomy (RARP) is a common method of minimally invasive surgical treatment for prostate cancer. Much of its popularity has been attributed to studies that consistently show potential decreased length of hospital stay, blood loss,[2] and comparable pathological outcomes, when compared with open surgery.[3]

There are several steps to RARP, for example, docking the robot, dissecting the seminal vesicles (SVs), dorsal venous complex ligation, lymph node dissection, and so on. One study showed that experience is associated with overall improvement in time, but that the various components have different rates of progress,[4] likely due to the relative complexities within the particular portion of the procedure. To our knowledge, there is no study investigating the components of the RARP and identifying their respective learning curves (LCs). Also, most of the studies on robot surgery LC are from surgeons who had already achieved expertise in open surgery techniques, rather than evaluating newly trained urologists in this dominantly minimally invasive surgery era.

In the present study, using the cumulative sum (CUSUM) analysis, we evaluated the LC for the RARP performed by a single surgeon in an urban hospital setting, who had recently completed fellowship training at a Society of Urologic Oncology-accredited urologic oncology program. We then further analyzed the LC of the specific procedural components of the RARP to identify what areas contributed to the LC of RARP and if there was any significant variability within the procedure. Cumulative sum analysis has been used in a variety of applications, including medical literature[5] and surgical education,[6] and very recently been applied to urologic surgery.[7] Cumulative sum allows for formation of a visual graph that detects minor changes, which can be useful to determine if objective improvement has occurred over time. Our objective was to apply CUSUM charting to analyze and evaluate surgeon operating room time performance in RARP.

2. Materials and methods

We conducted a retrospective study of RARP performed by a single urologist (M.M.S.) who had recently completed his oncologic fellowship training before joining the faculty at an urban tertiary care referral center. Robotic-assisted radical prostatectomy performed between August 15, 2015, and April 26, 2019, was included, and patients' demographic information, operation time, and perioperative outcomes were gathered and analyzed.

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Table 1

Demographics and perioperative characteristics of our patient cohort (n = 120) with a comparison of the patients before and after a learning curve in total procedural time was established (25 vs. 101).

Characteristics	All patients (n = 120)	Pre–learning curve (n = 25)	Post–learning curve (n = 95)	*p*
Age, mean (SD), yr	59.6 (6.8)	58.2 (6.2)	60.0 (6.9)	0.3
Race, n (%)				0.3
Black/African American	63 (52.1)	17 (68.0)	46 (48.4)	
White/Caucasian	51 (42.9)	7 (28.0)	44 (46.3)	
Other	6 (5.0)	1 (4.0)	5 (5.3)	
BMI, kg/m^2	28.5 (4.2)	29.4 (4.5	28.3 (4.1)	0.2
Preoperative PSA, ng/mL	9.8 (8.2)	8.0 (4.7	10.3 (8.9)	0.2
Preoperative clinical T staging, n (%)				0.3
1	0 (0.0)	0 (0.0)	0 (0.0)	
2	77 (63.3)	16 (64.0)	61 (64.2)	
3	43 (35.7)	9 (36.0)	34 (35.8)	
4	0 (0.0)	0 (0.0)	0 (0.0)	
Gleason score, n (%)				0.3
6	2 (1.7)	1 (4.0)	1 (1.1)	
7	98 (81.7)	22 (88.0)	76 (80.0)	
≥8	20 (16.7)	2 (8.0)	18 (18.9)	
Prostate volume, mL	51.3 (20.4)	46.6 (19.0)	52.5 (20.7)	0.2
Tumor burden, %	37.0	33.0	38.0	0.8
Conversion rate, n (%)	0 (0.0)	0 (0.0)	0 (0.0)	
Prior prostate surgery, n (%)				0.8
No	107 (89.2)	23 (92.0)	84 (88.4)	
Yes	13 (10.8)	2 (8.0)	11 (11.6)	
Prior pelvic/abdominal surgery, n (%)				0.5
No	84 (70.0)	19 (76.0)	65 (68.4)	
Yes	36 (30.0)	6 (24.0)	30 (31.6)	

BMI = body mass index; PSA = prostate-specific antigen.

2.1. Operative procedures

After having properly consented, all patients received RARPs under general anesthesia. The RARP was divided into 7 main parts, and the durations of each step were prospectively recorded in real-time during the procedure by the surgeon.

2.1.1. Docking the robot The patient was positioned supinely, placed in a dorsal lithotomy position. After time-out, ports, including camera, 3 robotic and 2 assistant ports, were inserted. The patient was placed in 30-degree Trendelenburg position, and the robot docked.

2.1.2. Dissecting the SVs This process included incision of the posterior plane of the peritoneum above the SVs and dissection of vas deferens and SVs.

2.1.3. Dissecting the endopelvic fascia This included the incision of Denonvilliers' fascia and endopelvic fascia (EPF) to expose the posterior and anterior prostate and ligation of the dorsal venous complex.

2.1.4. Incising the bladder neck Incision of bladder neck (BN) often as clinically appropriate was performed with BN-sparing technique.

2.1.5. Completion of prostate dissection A prostatectomy was performed to the prostate apex, the urethra was transected in this step, and the specimen was placed in a bag.

2.1.6. Lymph node dissection The lymph node dissection had significant variability between cases, but in general, bilateral obturator lymph nodes were dissected.

2.1.7. Urethrovesical anastomosis and undocking the robot This included the urethrovesical anastomosis (UVA), drain placement in select cases, robot undocking, and specimen removal.

2.2. Statistical analysis

Cumulative sum analysis was used to identify an LC by obtaining a trend line that indicates predictable change is occurring and is not due to random fluctuations in cases. Cumulative sum analysis works by using the raw data and graphing it based on deviations in the data relative to a prespecified target. As each subsequently analyzed case deviates above or below a target, the curve is adjusted up or down based on the amount the new case outperformed or underperformed the target. In behaviors that demonstrate an LC, a transition from an upsloping curve (consistently underperforming the target) to a downsloping curve (consistently outperforming the target) is observed. For our analysis, we used data from a recent article that was consistent with a mean of 240 minutes for a multipart radical prostatectomy for an experienced surgeon.[8] Because the literature on specific components of the RARP is limited, the target for each curve was the average time of the component as a fraction of the total operative time. The output graph is a visualization of the data trends. When the cases start having less variability and is more static, it indicates that an LC has been achieved, and outcomes are not due to randomness. Continuous and binary variables were compared using *t* test and chi-square analysis, respectively. All statistical analyses were performed using Prism statistical software and Microsoft Excel 365 (Microsoft Inc, Redmond, WA). All procedures

Table 2

Minimal absolute number of cases to achieve a learning curve and its relative impact on decreasing operative time, percentage of time reduced, and decrease in variability between cases.

Procedure	All cases, mean (SD)	Learning curve case, n	R^2	Pre–learning curve, mean (SD)	Post–learning curve, mean (SD)	% Decrease (time)	% Decrease in variability	*p*
Total operative time	218.9 (50.4)	25	0.99	267.0 (59.2)	206.2 (41.0)	22.8	55.8	*<0.0001*
Robot docking	24.0 (8.4)	13	0.97	28.2 (10.1)	23.5 (8.1)	16.7	34.7	*0.03*
Dissecting seminal vesicles	24.7 (9.2)	33	0.99	31.7 (9.7)	22.1 (7.4)	30.5	41.5	*<0.0001*
Dissecting endopelvic fascia	22.4 (9.6)	31	0.99	28.8 (11.0)	20.2 (8.1)	29.6	46.4	*<0.0001*
Incising bladder neck	21.9 (11.0)	46	0.99	28.2 (12.8)	18.0 (7.3)	36.2	67.4	*<0.0001*
Completing prostate dissection	26.7 (12.8)	38	0.99	35.8 (15.7)	22.5 (8.5)	37.3	70.6	*<0.0001*
Lymph node dissection	22.9 (12.8)	25	0.97	30.8 (14.3)	20.9 (11.6)	32.2	34.4	*0.004*
Urethrovesical anastomosis	38.8 (17.2)	52	0.98	45.8 (19.4)	33.5 (13.2)	26.9	53.5	*<0.0001*

Italic font is the *p*-value is for the comparison of the operative times between pre–learning curve and post–learning curve.

in this study were performed in accordance with ethical standards of the institutional and national research committee.

3. Results

A total of 120 consecutive cases were included from August 15, 2015, to April 26, 2019. The demographics and perioperative characteristics of our patient cohort are shown in Table 1. The mean age was 59.6 (SD, 6.8) years. Sixty-three patients (52.1%) were African American, and 51 (42.9%) were Caucasian. The mean prostate volume was 51.3 (SD, 0.4) mL. The mean preoperative prostate-specific antigen level was 9.8 (SD, 8.2) ng/mL. The clinical stage was split between T2 (63.3%) and T3 (35.7%), and majority of patients had a Gleason score of 7 (81.5%). There were no conversions to open procedures.

We analyzed all parts of the RARP procedure using the CUSUM method with an overlying polynomial trend line, and the LC absolute values are summarized in Table 2. On the CUSUM graph, a down-trending line begins to form when there is achievement of

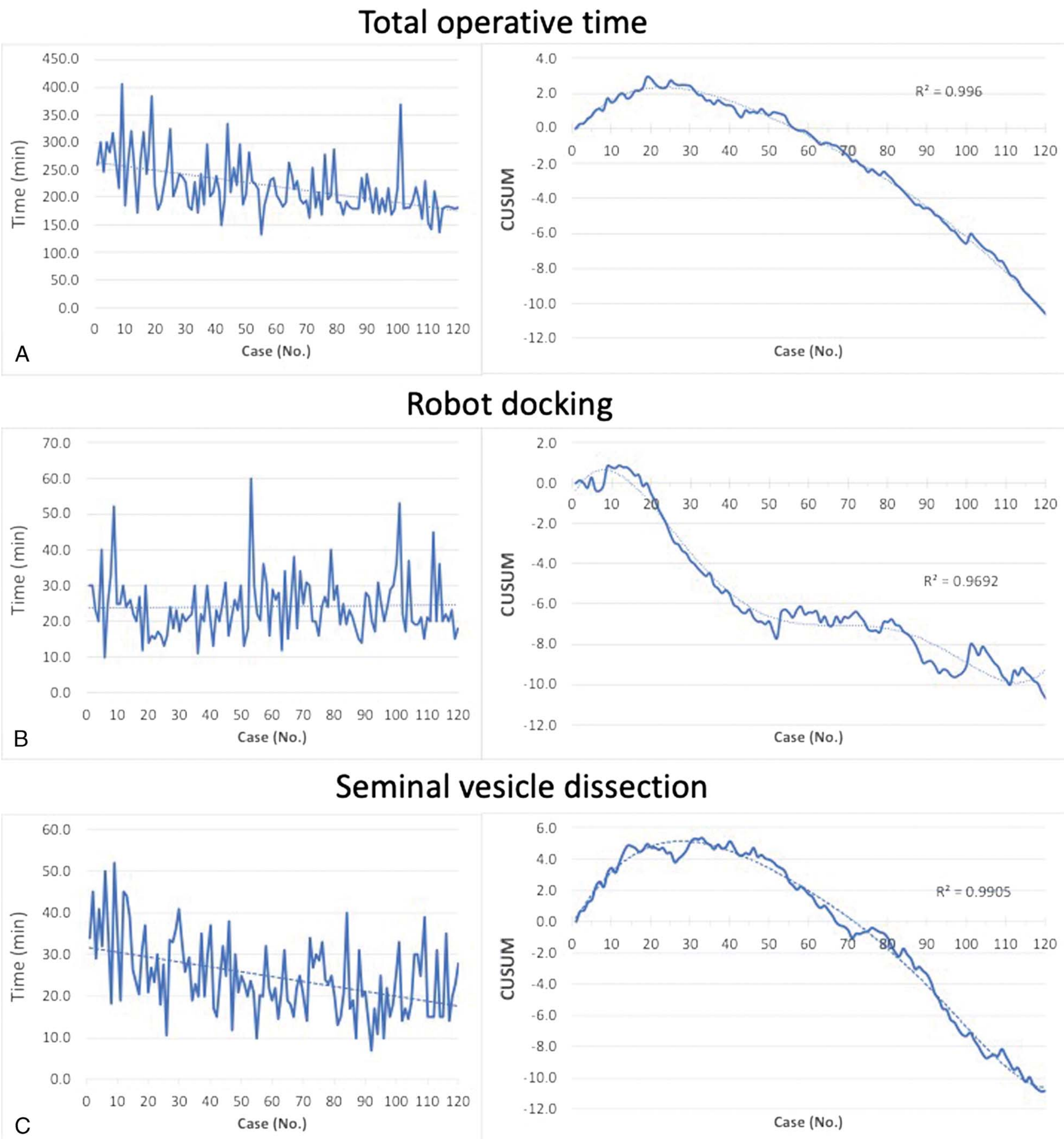
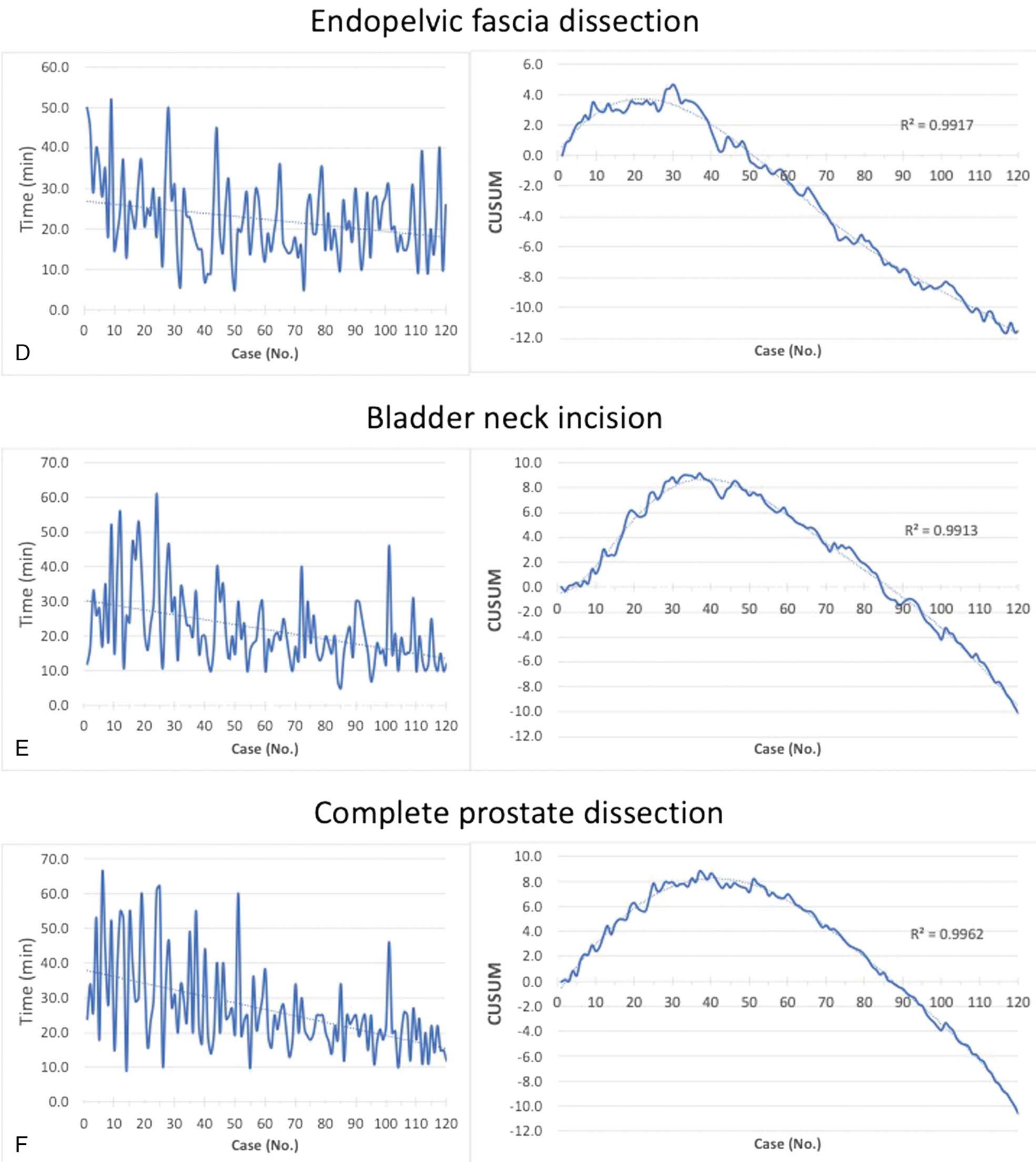


Figure 1. Raw data (left panel) and CUSUM analysis (right panel) for (A), total operative time, (B) docking the robot, (C) dissecting seminal vesicles, (D) dissecting endopelvic fascia, (E) incising bladder neck, (F) prostate in bag, (G) LN dissection, and (H) undocking the robot. The arrow indicates the point at which consistency is being reached, representing the target number for proficiency in that aspect of the robotic-assisted radical prostatectomy. CUSUM = cumulative sum.



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a successful LC. The LC for the entire procedure was overcome after 25 cases (R^2 = 0.99). Docking the robot was established after 13 cases (R^2 = 0.97); dissecting SVs, 33 cases (R^2 = 0.99); dissecting EPF, 31 cases (R^2 = 0.99); incising BN, 46 cases (R^2 = 0.99); and dissecting and placing prostate in the bag were achieved at 38 cases (R^2 = 0.99). Lymph node dissection showed an LC after 25 cases (R^2 = 0.97), and UVA and undocking the robot were achieved after 52 procedures (R^2 = 0.98) (Fig. 1).

The operative time raw data with a comparison of the cohort before and after an LC for each aspect of the procedure are shown in Table 2. In minutes, total operative time was 218.9 (pre-LC 267.0 vs. post-LC 206.2; percentage of reduction [PR] = 22.8%). Mean times for docking the robot was steady at 24.0 (pre-LC 28.2 vs. post-LC 23.5; PR = 16.7%). Dissecting SVs was 24.7 (pre-LC 31.7 vs. post-LC 22.1; PR = 30.5%); dissecting EPF, 22.4 (pre-LC 28.8 vs. post-LC 20.2; PR = 29.6%); incising BN, 21.9 (pre-LC 28.2 vs.

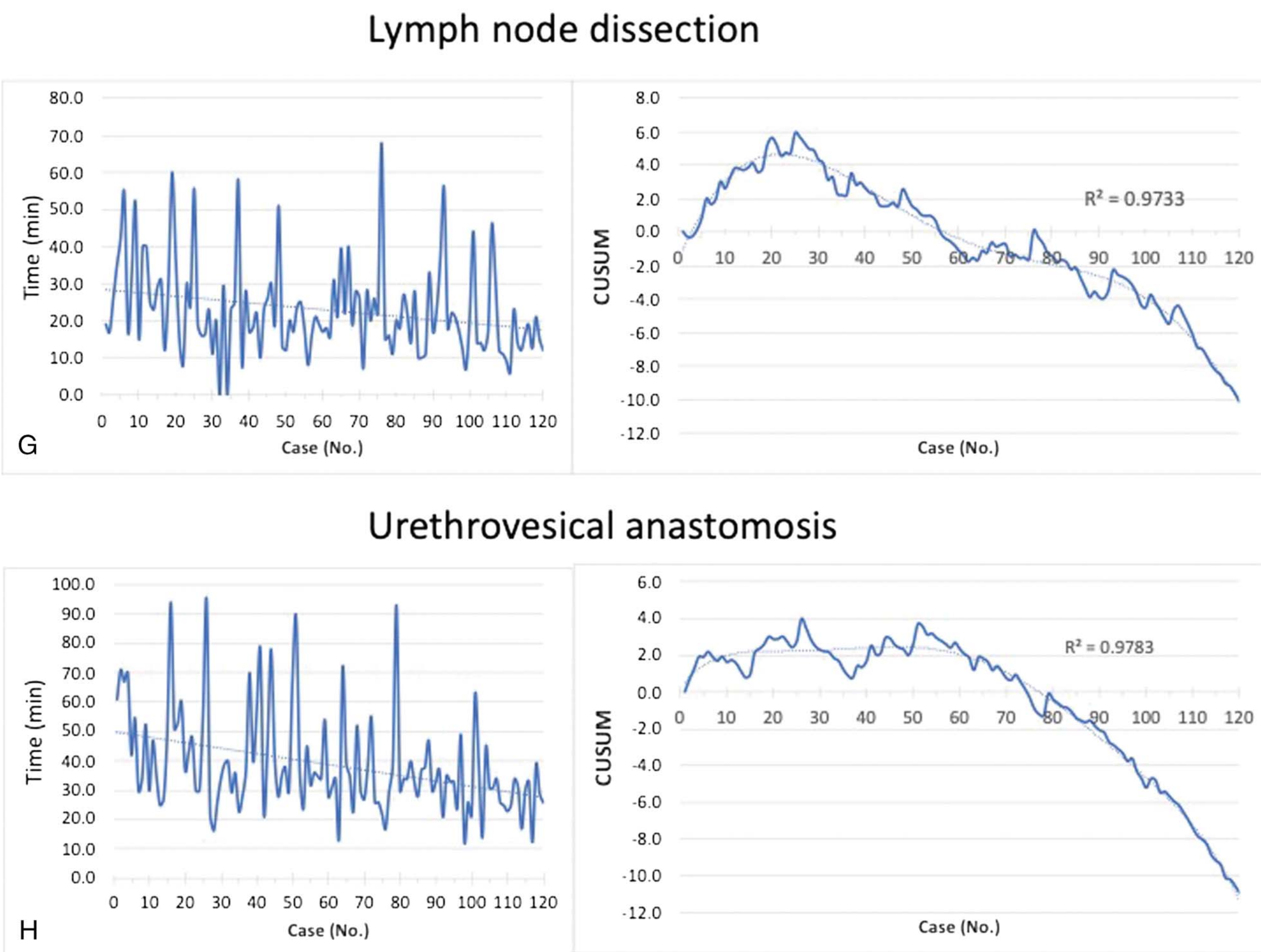

Figure 1. Continued.

post-LC 18.0; PR = 36.2%); dissecting and placing prostate in bag, 26.7 (pre-LC 35.8 vs. post-LC 22.5; PR = 37.3%); LN dissection, 22.9 (pre-LC 30.8 vs. post-LC 20.9; PR = 32.2%); and UVA and undocking the robot, 38.8 (pre-LC 45.8 vs. post-LC 33.5; PR = 26.9%).

It was especially notable that LC was associated not only with decrease in time but also, perhaps more significantly, a decrease in variability (Table 2). Particularly, the prostate dissection steps demonstrated the greatest magnitude decrease in time by 37.3%, whereas decrease in variability of times to perform the various steps decreased between 34.7% and 70.6% in all steps.

4. Discussion

Previous studies have acknowledged that there is an LC for robotic surgery, largely influenced because of the loss of tactile feedback and difficulty internalizing the mechanics of the robot. Surgeon skill and experience have been associated with less complications,[9] and there have been a few studies describing veteran surgeons adopting robotics for radical prostatectomies and over time having better intraoperative experiences including decreased blood loss and intraoperative time,[10] and fewer adverse events in the follow-up period.[11] Islamoglu et al.[12] reported that an experienced surgeon would need at least 50 cases to achieve the LC for satisfactory oncologic outcomes. Wolanski et al.[13] found that veteran surgeons do have a significantly decreased LC when compared with the novice surgeon regarding outcomes, and this possibly can be true for operative time efficiency as well. One study looking at the LC for total operative time for surgeons experienced in retropubic radical prostatectomy was approximately 32 cases.[14] However, most of the studies have focused on veteran surgeons who transitioned from an open to a robotic approach. Furthermore, there is significant concern for lack of tools to measure and evaluate robotic training, regarding time and efficiency.[15]

When a new operative procedure is introduced, important aspects to evaluate the success of a procedure are the outcomes and incidence of postoperative complication risk and also importantly the evaluation of operative time. The procedural time can be evaluated by analyzing the LC. The CUSUM method has been used to evaluate prostatic robotic surgery[15] and monitor technical skills and trends over time. Cumulative sum analysis is a statistical graphic that can be used to monitor the success and failure at a technical skill and examines trends over time. It can be used to demonstrate proficiency in a newly learned technical skill and determine whether a resident has achieved competency in a particular skill. The CUSUM method is notable in that it does not presuppose any set LC or even the presence of an LC. It can therefore help identify LCs without bias to assumptions before analysis.

In the present study, using the CUSUM method, total procedure and component-based operative times were examined in the RARP procedure. This study involved 120 consecutive cases, and all procedures were performed by a single surgeon who had recently finished residency and fellowship training and was a new attending surgeon in a tertiary referral urban hospital. Although the overall LC appeared to be approximately 25 cases for this transition, we did observe shorter and longer LCs for various components of the procedure. When dividing the procedure into checkpoints, we observed that there are certain parts to the operation that have shorter LCs, such as dissection of the SV and EPF dissection at 33 and 31 cases, respectively. Other components, such as incising the BN and performing the UVA, required 46 and 52 cases, respectively. It is furthermore worth noting that the LC observed in our study is of shorter duration than noted in other studies, which ranged from 100 to 150 cases.[16,17] We hypothesize that this LC disparity may reflect differences in incoming training and that a robotically trained urologic oncologist starting a new practice has a different LC than a surgeon adapting robotics for the first time. Further studies may flesh out these details.

Our study has some limitations. We studied only 1 surgeon in 1 hospital setting, and our results may not be reproducible with other surgeons. However, in contrast to previous studies that focused on surgeons with extensive open experience and many years in practice, our study participant was a new surgeon and is more applicable to trainees who are training to learn urologic surgery primarily using robotics. We believe that our results can be applied for such individuals under the assumption that there is a baseline similarity among Society of Urologic Oncology–accredited American fellowship opportunities. Furthermore, the LC of operative time relies not only on the surgeon but also on the entire surgical team, which we did not have available data on. Finally, operative time alone is important, but there are other important factors, namely, oncologic outcomes and complication rates that would be important measures to address in future studies, and is a significant limitation to our study. However, operative time is an important consideration for any LC and may significantly impact education and practice changes.

In summary, we observed a 25-case LC for a fellowship-trained urologist to achieve stable operative performance of RARP surgery in a newly independent setting. Different components of the procedure demonstrated variable LCs upward of 52 cases. The UVA of RARP required the greatest amount of performances to establish an LC and minimize variability.

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None.

Statement of ethics

This retrospective study involved deidentified information and was exempt by the University of Maryland School of Medicine Institutional Review Board. This research involved deidentified information involving human participation and did not require consent in accordance with ethical standards of the institutional and national research committee. All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee(s) and with the Helsinki Declaration.

Conflict of interest statement

No conflict of interest has been declared by the authors.

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Author contributions

DA: Data collection and management, data analysis, manuscript writing/editing;
SW: Data analysis, manuscript writing/editing;
MMS: Project development, data collection and management, data analysis, manuscript writing/editing.

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