ANTICANCER RESEARCH *41*: 4173-4178 (2021)
doi:10.21873/anticanres.15222

Learning Curve of Robotic-assisted Hysterectomy With Pelvic Lymphadenectomy for Early Stage Endometrial Cancer: Analysis of 81 Cases

MUNETOSHI AKAZAWA[1], KAZUNORI HASHIMOTO[1], SHENG-LUN LEE[2#] and WEI-MIN LIU[2#]

[1]*Department of Obstetrics and Gynecology, Tokyo Women's Medical University Medical Center East, Tokyo, Japan;*
[2]*Department of Obstetrics and Gynecology, Taipei Medical University Hospital, Taipei, Taiwan, R.O.C.*

Abstract. *Background/Aim: The purpose of this study was to evaluate the learning curve of robotic hysterectomy and pelvic lymphadenectomy for early-stage endometrial carcinoma. Patients and Methods: A retrospective chart review was performed on the first 81 surgeries performed by a single surgeon. The 81 cases were divided into three groups; 4 subgroups of 20 cases each, 3 subgroups of 27 cases each, and 2 subgroups of 40 cases each. The surgical outcomes in each group were analyzed, using operative time, estimated blood loss, and the number of lymph nodes resected. Results: The median operating time, estimated blood loss, and number of pelvic lymph nodes were 147 min, 50 g and 23, respectively. The estimated blood loss improved over time significantly, when dividing by every 27 and 40 cases. No statistical significance was shown regarding operative time and the number of lymph nodes. Conclusion: Approximately, 30 cases were needed to gain proficiency in the surgical technique.*

Endometrial cancer is the most frequently occurring malignant tumor of the female genital tract. Traditionally, surgical treatment included laparotomy, but recent progress in minimally invasive techniques has led to dramatic changes in the surgical approach. Previous analyses have supported the feasibility and safety of minimal invasive surgery for early endometrial cancer (1, 2). However, the educational costs of minimally invasive surgery have served as a barrier to the implementation of these techniques.

#These Authors contributed equally to this study.

Correspondence to: Dr Sheng-Lun Lee, Department of Obstetrics and Gynecology, Taipei Medical University Hospital and Taipei Medical University, No. 252, WuXing St., XinYi District, Taipei 11031, Taiwan, R.O.C. Tel: +886 227372181, e-mail: judy0092@gmail.com

Key Words: Robotic surgery, learning curve, endometrial cancer.

The learning curve of minimally invasive surgeries has been frequently analyzed. In laparoscopy, a steep learning curve exists due to counterintuitive motion, surgeon training, and experience. Globally, laparoscopic surgery rate for endometrial cancer was low, which was most likely related to this steep learning curve. In contrast, robotic surgery has been rapidly accepted by surgeons worldwide due to the enhanced visualization, movements, and ergonomics (1). Compared with laparoscopy, the learning process of robotic surgery was originally perceived as shorter since the three-dimensional view of robotic laparoscopy allows for a significantly better performance and faster improvement (3). In previous studies of minimally invasive surgeries for endometrial cancer, robotic surgery required less cases to obtain proficiency compared with laparoscopy (2).

Surgical outcomes have been reported to improve with 20-60 cases in minimally invasive surgery for endometrial cancer. However, the number of cases needed for a surgeon to obtain proficiency is unclear. To compare surgical outcomes, previous studies divided the cases chronologically into several subgroups of 15-30 cases each. In order to evaluate the learning curve of robotic surgery in particular, we divided the number of cases in several ways: every 20, 27, and 40 cases. We evaluated the impact of the first 20/27/40 cases on the subsequent cases. The purpose of this study was to evaluate learning curves of surgical proficiency in robotic surgery for early endometrial cancer.

Patients and Methods

We conducted a retrospective, cross-sectional chart review of patients who underwent robotic-assisted staging surgery from January 2012 to March 2016 by a single surgeon in a tertiary care referral hospital. Indication criteria included early-stage endometrial cancer [preoperatively considered as International Federation of Gynecology and Obstetrics (FIGO) stage I and II of endometrial cancer]. Preoperative diagnosis was performed by computed tomography (CT) and magnetic resonance imaging (MRI). All surgeries were performed by a single surgeon with 40 years of experience as a gynecologic surgeon. The surgeon began performing robotic hysterectomies in April 2011.

We analyzed the patients' clinical background [age, body mass index (BMI), and parity], pathological diagnosis, the weight of uterus, surgical outcomes (operative time, estimated blood loss, the number of lymph nodes, incidence of complications, and incidence of conversion to laparotomy) and hospital stay. Operative time was defined as time from first incision to skin closure, including docking and console times. Estimated blood loss was determined by the amount of bleeding through suction tube (minimal blood loss was defined as 10 ml). We did not use small gauze in abdominal cavity. The complications were confirmed by the review of patients' records like re-admission or visit of emergency rooms.

The three-armed standard da Vinci® surgical robot (Intuitive Surgical Inc., Sunnyvale, CA, USA) was used. Four trocars were placed into the abdomen of the patient. A long 12-mm Hasson trocar was passed through the umbilicus, while two 8-mm robotic trocars were placed bilaterally at the level of the umbilicus. An accessory 10-mm trocar was placed between the left anterior superior iliac spine and the left lateral trocar. After the three-arm robotic tower was situated between the patient's legs, a laparoscope was introduced through the umbilical trocar, a monopolar spatula through the right lateral trocar, and a bipolar grasper through the left lateral trocar. All surgeries were similar to the conventional laparoscopic hysterectomy. The vaginal cuff was closed using two layers of continuous sutures, with the intracorporal knotting technique used for all cases. We adopted the vaginal technique for vault closure in order to decrease the number of robotic arms and suppress the surgical cost. The uterus and adnexa were removed through the vaginal opening. In difficult cases such as obese and nulliparous patients, we added transverse incision in lower abdomen, that is mini-laparotomy (usually transverse 3-4 cm incision 2 fingers above pubis), and removed the specimen.

Statistical analyses were performed using R Statistical Software (Foundation for Statistical Computing, Vienna, Austria). Because skewness was suspected on plotting a frequency histogram of measurement data, the nonparametric Mann-Whitney's *U*-test/Kruskal-Wallis tests were used and the data were reported as medians and ranges. For categorical data, Pearson's χ^2 test was used, reported as frequencies and percentages. Two-sided p-values of <0.05 were considered significant. First, the learning curve was estimated by operative time, estimated blood loss and the number of lymph nodes resected chronologically. Second, the 81 cases were divided into three groups. In Group 1, cases were chronologically divided into 4 subgroups of 20 cases each. In Group 2, cases were chronologically divided into 3 subgroups of 27 cases each. In Group 3, cases were chronologically divided into 2 subgroups of 40 cases each. Comparing surgical outcomes of subsequent subgroups, the learning curve was analyzed. The Bonferroni procedure was used to adjust the p-value between each of the several comparisons.

The Institutional Review Board deemed this study exempt from review as it involved analysis of existing, de-identified data.

Table I. *Patient demographics and surgical-pathological data.*

Age (year)	54 (30-82)
BMI (kg/m^2)	26.3 (11-49)
Parity	2 (0-5)
FIGO stage	
IA	55 (67.9%)
IB	15 (18.5%)
II	1 (1.2%)
IIIA	2 (2.4%)
IIIC	6 (7.4%)
The weight of uterus (g)	155 (85-835)
Operative time (min)	147 (80-345)
Estimated blood loss (g)	50 (50-300)
The number of lymph node	23 (6-44)
The number of conversion cases	0
The number of complication cases	2 (2.4%)
Hospital stay (days)	3 (1-7)

Data were median (range), n(%).

Results

The patient demographics are shown in Table I. Median patient age was 54 years and median BMI was 26.3. International Federation of Gynecology and Obstetrics (FIGO) stage was as follows: stage 1A (67%), stage 1B (18%), stage 2 (1.2%), stage 3A (2.4%), and stage 3C (7.4%). Median weight of the uterus was 155 g, and the largest size was 835 g due to multiple myomas. Median operative time was 147 min, median blood loss was 50 g, and median number of pelvic lymph nodes resected was 23. Intraoperative complications did not occur in any of the cases, yet postoperative complications occurred in 2 cases (2.4%) (surgical site infection and vaginal cuff dehiscence). There was no case of conversion to laparotomy. On average, hospital stay was three days.

Figures 1, 2 and 3 show the surgical outcomes plotted chronologically according to the case number. Estimated blood loss decreased significantly with increasing case number. The results suggested that operative time decreased with increasing case number, in contrast, the number of lymph nodes resected decreased with surgeon experience, though this change was not significant.

Table II shows the results of surgical outcomes divided by every 20, 27, and 40 cases. In every-20-cases groups, no significant improvement in any area was shown in Kruskal-Wallis tests. When comparing the two subsequent groups in the 20-cases groups, there was no difference in operative time, blood loss, or the number of lymph nodes resected. In the 27-cases groups, blood loss decreased significantly between the first and second groups, but not between the second and third groups. Operative time decreased among the groups; however, this difference was not significant. Regarding the lymph nodes resected, no trends are shown. In the 40-cases groups blood loss decreased significantly, while operative time and the number of lymph nodes resected did not change.

Discussion

The learning curve of surgical proficiency in minimally invasive surgeries has been analyzed in many studies (3-12). The detailed analysis of the number of procedures required

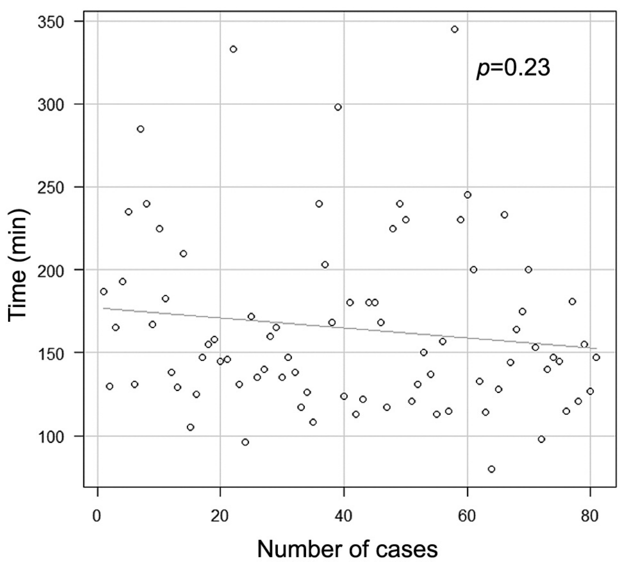

Figure 1. *The linear regression curve demonstrating the relation between operative time and operator.*

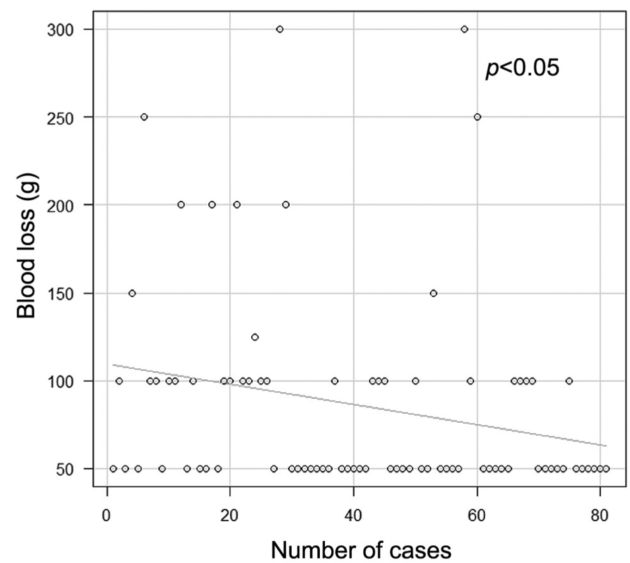

Figure 2. *The linear regression curve demonstrating the relation between estimated blood loss and operator experience.*

for proficiency is extremely important in clinical practice. Based on the results of these learning curve investigations, a more definite and cost-effective educational system could be constructed. This would inevitably lead to increased surgical quality in each hospital. Moreover, proficiency in avoiding surgical complications is achieved after obtaining a feasible Technique (4).

Several studies have been published analyzing minimally invasive surgery for endometrial cancer. Eltabbakh evaluated the learning curve of laparoscopy (5). The authors divided 75 cases into every 30 cases and concluded that 50 cases were required to achieve optimal performance in laparoscopic surgery. In addition, they recommended that a surgeon with comfortable experience in laparoscopy for benign diseases needs to be invigilated in the first 10 cases of laparoscopic pelvic and para-aortic lymph node sampling. In the field of robotic surgery, Seamon analyzed 92 cases of robotic surgeries and determined that 20 cases were required to obtain proficiency (6). They analyzed the operative time, dividing the full operative time into several parts such as "console time", "incision to docking", and "room to incision time". The authors showed that each time block improved with the increase of robotic operations. Lim compared the learning curve of robotic surgery with laparoscopy for endometrial cancer, analyzing 122 cases of robotic and 122 cases of laparoscopic surgeries (3). In this analysis, 20-25 cases were required to obtain proficiency in robotic surgery. In contrast, 49 cases were required for laparoscopy. The authors concluded that robotic hysterectomy with lymphadenectomy has a faster learning curve compared to laparoscopic hysterectomy with lymphadenectomy.

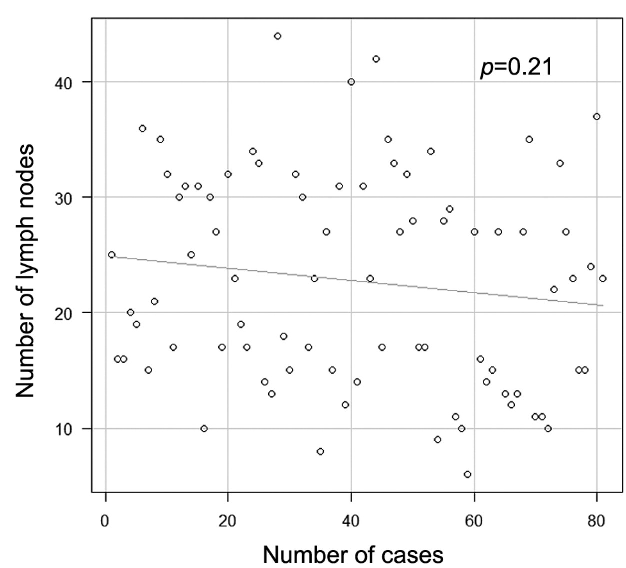

Figure 3. *The linear regression curve demonstrating the relation between the number of lymph node resected and operator experience.*

We reviewed these studies and summarized their outcomes (Table III) (3-12). In summary, 20-60 cases were required to gain proficiency in minimally invasive surgery for endometrial cancer. Comparing surgical approaches, as mentioned above, it has been shown that robotic surgery has a faster learning curve than laparoscopic surgery. Regarding the factors used to analyze surgical outcomes, "operative

Table II. *Surgical outcomes during the learning curve in chronological order.*

Every 20 cases	Group 1 (cases 1-20)	Group 2 (cases 21-40)	Group 3 (cases 41-60)	Group 4 (cases 61-81)	*p*-Value	*p*-Value group 1 *vs*. 2	*p*-Value group 2 *vs*. 3	*p*-value group 3 *vs*. 4
N	20	20	20	21				
Operative time	161.5	143	162.5	145	0.393	0.32	0.57	0.25
Blood loss	100	50	50	50	0.097	0.48	0.73	0.18
Number of lymph nodes	25	21	27	16	0.365	0.56	0.92	0.22

Every 27 cases	Group 1 (cases 1-27)	Group 2 (cases 28-56)	Group 3 (cases 57-81)	*p*-Value	*p*-Value group 1 *vs*. 2	*p*-Value group 2 *vs*. 3
N	27	27	27			
Operative time	156	147	147	0.633	0.413	0.98
Blood loss	100	50	50	0.005	0.0004	0.84
Number of lymph nodes	24	27	15.5	0.052	0.98	0.11

Every 40 cases	Group 1 (case 1-40)	Group 2 (case 41-81)	*p*-Value
N	40	41	
Operative time	155	147	0.357
Blood loss	100	50	0.029
Number of lymph nodes	23	23	0.466

Table III. *The review of the literature regarding the learning curve.*

Author	Year	Number of cases	Included surgeons	Surgical approach	Analysis designs	Number of cases needing for proficiency	Operative time	Blood loss	Number of lymph nodes
Tucker *et al*. (10)	2020	194	7	Robotic	Evaluating the performance by successful staging with sentinel lymph node biopsy	40 cases	nd	nd	nd
Kim *et al*. (12)	2020	80	1	Robotic	Evaluating the performance by successful staging with sentinel lymph node biopsy	27 cases	nd	nd	nd
Seamon *et al*. (6)	2009	79	2	Robotic	Divided by every 20 cases	20 cases	○	×	×
Holloway *et al*. (7)	2009	100	5	Robotic	Divided by every 50 cases and every 15 cases	nd	○	nd	○
Torng *et al*. (11)	2017	20 24	nd	Robotic Laparoscopic	nd	20 cases for robotic over 24 cases for laparoscopy	○	○	×
Lim *et al*. (3)	2011	122 122	nd	Robotic Laparoscopic	nd	24 cases for robotic 49 cases for laparoscopy	○	○	×
Yoshida *et al*. (4)	2020	134	1	Laparoscopic	Cumulative sum analysis	60 cases	○	nd	○
Togami *et al*. (9)	2019	82	1	Laparoscopic	Divided by every 20 cases	nd	○	○	×
Holub *et al*. (8)	2003	108	2	Laparoscopic	Divided by every 36 cases	30 cases	○	×	○
Eltabbakh (5)	2000	75	1	Laparoscopic	Divided by every 25 cases	50 cases	○	×	○

○: Improved significantly; ×: did not improve significantly; nd: not described.

time," "estimated blood loss," "the number of lymph nodes," and "length of hospital stays" were adopted in these studies. In addition to these surgical factors, two studies used the positive rate of successful staging with sentinel lymph node biopsy. Many authors included operative time as a measure, and operative time was shown to decrease with surgeon experience (3-9, 11). Estimated blood loss and the number of lymph nodes resected were evaluated by several authors and the results are controversial (3-9, 11). Estimated blood loss decreased with increasing numbers of surgeries, but this did not gain statistical significance in several analyses (5-6, 8). The number of lymph nodes resected was also controversial (3-9, 11). Some authors reported that the number of lymph nodes resected did not change chronologically (6, 9), while others stated improvement (7, 8). The detection rate of sentinel lymph node has been shown to improve with the number of surgeries (10, 12).

Our analysis was the first to evaluate surgical outcomes, dividing the cases in a different manner than previous studies. In previous studies, the cases were divided into groups of specific numbers by each author. However, the reasons for choosing the number of cases used for classification were unclear. In the current study, surgical outcomes were evaluated by several factors and each group was analyzed. Regarding operative time, in the 27-cases group and the 40-cases group, clinical improvement was suggested, though not shown to be significant. However, in the 20-cases group, the trend was not evident at all. In contrast, estimated blood loss after 20 cases reached a plateau, and no further improvement was observed. In the first 20 cases, blood loss was found to be more copious, so the impact of the first 20-cases was observed in the 27-cases and 40-cases groups. The number of lymph nodes resected did not change. In the first decades, the number of lymph nodes seemed to be greater. In summary, operative time showed a plateau after 30-40 cases, while blood loss improved considerably after the first 20 cases. In this study, our data indicate that the learning curve differs between operative time and blood loss.

The limitation of our report is the retrospective nature of the study as we only reviewed data from medical records. Second, since the surgeon also performed robotic surgeries for benign disease in the study period, the experience of benign disease could have an impact on the surgical outcomes. In the staging surgery for early endometrial cancer, the main part of the surgery is the hysterectomy itself. Therefore, as a surgeon performs more robotic hysterectomies for benign disease, the proficiency of robotic surgeries in general also improves. The surgeon in this study also performed 500 cases of robotic surgeries for benign disease in the same study period. In addition, not only the experience in robotic surgeries but also in laparoscopic surgeries could have an impact on surgical outcomes. Lim stated that a surgeon's advanced surgical experience prior to adopting robotic surgery may contribute to achieving earlier proficiency in robotic surgery (3). Thus, because laparoscopic experience or robotic surgery for benign diseases can have a strong impact on surgical proficiency, analysis of the learning curve has a limitation due to the varied background of the specific surgeon. Last, we did not include evaluation of oncologic outcome of the procedures. In surgery for malignant disease, oncologic as well as surgical outcomes should be evaluated, especially with regard to lymph node resection. Additionally, the recurrence rate and overall survival rate should be compared among the groups.

In the current study, surgical outcomes improved with surgeons' experience. We also noted that different learning curves were found for reducing blood loss and operative times. Reduced blood loss was achieved after just 20 cases, while operative time required 30-40 cases to show a significant improvement.

Conflicts of Interest

The Authors have no conflicts of interest to declare regarding this study.

Authors' Contributions

MA conceived the idea of the study, analyzed the data and wrote the manuscript. SL and WL performed most of the clinical medicine and coordinated the project. KH was responsible for the writing, critical review, and final approval of the manuscript. WL shared information on clinical medicine and oversaw the entirety of the study.

Acknowledgements

The Authors would like to thank all the colleagues who, from different parts of the world, unselfishly enriched us with their opinions and suggestions.

References

1 Jørgensen SL, Mogensen O, Wu C, Lund K, Iachina M, Korsholm M and Jensen PT: Nationwide introduction of minimally invasive robotic surgery for early-stage endometrial cancer and its association with severe complications. JAMA Surg *154(6)*: 530-538, 2019. PMID: 30810740. DOI: 10.1001/jamasurg.2018.5840

2 Lim PC, Kang E and Park DH: A comparative detail analysis of the learning curve and surgical outcome for robotic hysterectomy with lymphadenectomy versus laparoscopic hysterectomy with lymphadenectomy in treatment of endometrial cancer: a case-matched controlled study of the first one hundred twenty two patients. Gynecol Oncol *120(3)*: 413-418, 2011. PMID: 21194735. DOI: 10.1016/j.ygyno.2010.11.034

3 Baeten I, Hoogendam JP, Schreuder H, Jürgenliemk-Schulz IM, Verheijen R, Zweemer RP and Gerestein CG: The influence of learning curve of robot-assisted laparoscopy on oncological

outcomes in early-stage cervical cancer: an observational cohort study. BJOG *128(3)*: 563-571, 2021. PMID: 32627934. DOI: 10.1111/1471-0528.16399
4 Yoshida H, Yamamoto M and Shigeta H: Learning curve of laparoscopic extraperitoneal para-aortic lymphadenectomy for endometrial carcinoma: A cumulative sum analysis. Surg Oncol *35*: 254-260, 2020. PMID: 32932223. DOI: 10.1016/j.suronc.2020.09.008
5 Eltabbakh GH: Effect of surgeon's experience on the surgical outcome of laparoscopic surgery for women with endometrial cancer. Gynecol Oncol *78(1)*: 58-61, 2000. PMID: 10873411. DOI: 10.1006/gyno.2000.5828
6 Seamon LG, Fowler JM, Richardson DL, Carlson MJ, Valmadre S, Phillips GS and Cohn DE: A detailed analysis of the learning curve: robotic hysterectomy and pelvic-aortic lymphadenectomy for endometrial cancer. Gynecol Oncol *114(2)*: 162-167, 2009. PMID: 19428096. DOI: 10.1016/j.ygyno.2009.04.017
7 Holloway RW, Ahmad S, DeNardis SA, Peterson LB, Sultana N, Bigsby GE 4th, Pikaart DP and Finkler NJ: Robotic-assisted laparoscopic hysterectomy and lymphadenectomy for endometrial cancer: Analysis of surgical performance. Gynecol Oncol *115(3)*: 447-452, 2009. PMID: 19765807. DOI: 10.1016/j.ygyno.2009.08.017
8 Holub Z, Jabor A, Bartos P, Hendl J and Urbánek S: Laparoscopic surgery in women with endometrial cancer: the learning curve. Eur J Obstet Gynecol Reprod Biol *107(2)*: 195-200, 2003. PMID: 12648868. DOI: 10.1016/s0301-2115(02)00373-1
9 Togami S, Kawamura T, Fukuda M, Yanazume S, Kamio M and Kobayashi H: Learning curve and surgical outcomes for laparoscopic surgery, including pelvic lymphadenectomy, for early stage endometrial cancer. Jpn J Clin Oncol *49(6)*: 521-524, 2019. PMID: 30855684. DOI: 10.1093/jjco/hyz027
10 Tucker K, Staley SA, Gehrig PA, Soper JT, Boggess JF, Ivanova A and Rossi E: Defining the learning curve for successful staging with sentinel lymph node biopsy for endometrial cancer among surgeons at an academic institution. Int J Gynecol Cancer *30(3)*: 346-351, 2020. PMID: 31911534. DOI: 10.1136/ijgc-2019-000942
11 Torng PL, Pan SP, Hwang JS, Shih HJ and Chen CL: Learning curve in concurrent application of laparoscopic and robotic-assisted hysterectomy with lymphadenectomy in endometrial cancer. Taiwan J Obstet Gynecol *56(6)*: 781-787, 2017. PMID: 29241920. DOI: 10.1016/j.tjog.2017.10.014
12 Kim S, Ryu KJ, Min KJ, Lee S, Jung US, Hong JH, Song JY, Lee JK and Lee NW: Learning curve for sentinel lymph node mapping in gynecologic malignancies. J Surg Oncol *121(4)*: 599-604, 2020. PMID: 31994195. DOI: 10.1002/jso.25853

Received May 22, 2021
Revised July 8, 2021
Accepted July 9, 2021