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Original article

Learning curve for laparoendoscopic single-site surgery for an experienced laparoscopic surgeon

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A B S T R A C T

Objectives: To assess the learning curve and safety of laparoendoscopic single-site (LESS) surgery of gynecological surgeries.
Materials and methods: Sixty-three women who underwent LESS surgery by a single experienced laparoscopic surgeon from February 2011 to August 2011 were included. Commercialized single-incision laparoscopic surgery homemade ports were used, along with conventional straight instruments. The learning curve has been defined as the additional surgical time with respect to surgical order of LESS surgery, which has been estimated using a smooth function in a linear model with generalized least squares, with some adjustments made due to influencing factors of the operations.
Results: All women completed LESS surgeries without the need for ancillary ports, except for two laparotomy conversions due to incidental ovarian malignancy. Three women, one with a gastrointestinal stromal tumor, one with laparoscopic myomectomy, and one who had been receiving simultaneous hysteroscopic myomectomy, were excluded. Of the 58 women included, 39 underwent adnexal surgeries and 19 underwent hysterectomies. Complications occurred with one woman who required a blood transfusion during the procedure. Surgical time was longer in bilateral cystectomy compared with unilateral cystectomy and unilateral/bilateral salpingo-oophorectomy (110.6 ± 51.1 minutes vs. 73.0 ± 26.3 minutes and 66.3 ± 26.9 minutes; $p < 0.03$); and in laparoscopic total/subtotal hysterectomy (LTH/LSH) compared with laparoscopic-assisted vaginal hysterectomy (LAVH) (205.6 ± 23.3 minutes vs. 120.1 ± 28.6 minutes; $P < 0.001$). The fitted linear model showed that surgical time was longer in cases with larger adnexal mass, more pelvic adhesion, and more blood loss. Surgical time was longer in LTH/LSH compared with LAVH. Surgical order of LESS surgery was not associated with surgical time.
Conclusion: LESS is a safe and feasible alternative to conventional laparoscopic surgery for adnexal and uterine diseases. A learning curve is not required for LESS surgery for experienced laparoscopic surgeons.

Introduction

Minimally invasive surgery is widely applied in gynecological surgeries, and one of the more recent advances in this field is the increasing use of single-port laparoscopic surgery. This type of surgical approach requires only one entry point, typically in the umbilical region. Many terms have been used in associated literature to describe single-port laparoscopic surgery, including single-port access surgery, single-incision laparoscopic surgery (SILS), embryonic natural-orifice transumbilical endoscopic surgery, one-port umbilical surgery, and transumbilical endoscopic surgery. The term laparoendoscopic single-site (LESS) surgery was recently agreed upon at the Cleveland Clinic, a reputable nonprofit academic medical center, for referring to all single-port laparoscopic surgeries.[1]

LESS surgery was first performed and reported on in 1969 for female sterilization,[2] in 1991 for uterine surgeries,[3] in 2001 for a case of ovarian surgery,[4] and in 2005 for 10 cases of ectopic pregnancy.[5] For a long period, LESS surgery was not recognized due to limitations of instrumentation, lighting, and access ports that increase its difficulty compared with the traditional laparoscope.

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LESS surgery became popular after 2009 with the invention of more advanced laparoscopic instruments to fulfill the requirements of more complicated procedures.[6] Using wound retractors with surgical gloves or commercial SILS for transumbilical port entrances, LESS was successfully established for use during adnexal surgeries[7–9] and in laparoscopic-assisted vaginal hysterectomies (LAVH).[10] Over the past few years, many experienced laparoscopic surgeons have shifted their surgical preference from conventional multiport laparoscopy to LESS surgery[11–14] because of the advantages of less postoperative pain and better cosmetic outcome.[15,16]

We shifted from multiport laparoscopy to LESS surgery in February 2011 and presented our initial consecutive cases of LESS surgery. In this study, we have analyzed the learning curve and safety of performing this new, minimally invasive gynecological surgical technique and identified factors influencing surgical time in LESS surgery.

Materials and methods

Patients

This study was conducted with approval from the institutional review board at The National Taiwan University College of Medicine. The prospective study included the experience of a single surgeon (Dr Torng) with 63 patients who underwent LESS surgery from February 2011 to August 2011 in a university hospital. Dr Torng, a gynecological oncologist, had 9 years of experience using multiport laparoscopic techniques for adnexal surgeries, laparoscopic myomectomies, and LAVH. Prior to her first LESS surgery case, Dr Torng observed LESS surgery from Dr T.J. Kim at Samsung Medical Center.

Patient data were arranged in surgical order according to the date of surgery and were classified into two groups: adnexal surgeries and hysterectomies. Demographic data including patient age, body mass index (BMI), and final diagnosis based on pathological reports; medical records of previous surgery were obtained. Surgical time and findings, including size of ovaries or uterine weight measured after operation, intraoperative adhesion (adhesion that bleeds at time of lysis or thick adhesion that requires sharp dissection), and estimated blood loss were recorded based on surgical notes. Surgical time was defined as the time from incision to skin closure. Data for intraoperative and postoperative complications were obtained from medical records. Complications were defined as intraoperative bleeding >500 mL, visceral organ injury, postoperative ileus that required prolonged hospitalization, postoperative hemorrhage that required treatment, postoperative infections, fistulas, thrombosis, embolism, or reoperation within 8 weeks, and wound complications. Hospital stay was recorded as from the time of admission to discharge.

Surgical technique

Surgical procedures were performed with the patient under general anesthesia and in a lithotomy position. The uterine manipulator was inserted into the uterine cavity in all patients except those who had no sexual experience and were receiving adnexal surgeries. The SILS port (Covidien, Mansfield, MA, USA) device was used on most patients. In some adnexal surgeries, a homemade single-port device was used with a surgical glove and wound retractor (Alexis, Applied Medical Resources Corp, Rancho Santa Margarita, CA, USA) as described previously.[8] The abdomen was inflated to a maximum pressure of 12 mmHg with carbon dioxide. All surgical procedures were performed with a rigid 0 degree 5-mm laparoscope and conventional rigid straight laparoscopic instruments.

The overall procedure for adnexal surgery and hysterectomy was similar to that performed during multiport laparoscopic surgery. For adnexal surgeries, the choice of cystectomy or salpingo-oophorectomy was based on the patients' age and the requirement of fertility sparing. Endobags (Endopouch, Unimax Medical System Corp, Taiwan; Endocatch, Covidien; homemade endobag using surgical glove with fingertips cut and tied) were used in all cases for ovarian mass retrieval from the umbilical incision. For larger ovarian tumors, a continuous rounding suture was used on the tumor surface facing the umbilical wound. A small puncture was made through the suture and the ovarian content was aspirated using a suction irrigation apparatus. The puncture site was securely tied to avoid leakage and the deflated ovarian cyst was pushed down to the pelvic cavity. Cystectomies or salpingo-oophorectomies were performed as usual. For hysterectomies, the LigaSure system (Valleylab, Boulder, CO, USA) was used for dissection and coagulation. Bilateral uterine arterial ligation was performed when the uterus was large.[17] For LAVH, anterior and posterior colpotomies and the vaginal stump suture were approached from the vagina. For laparoscopic subtotal hysterectomy (LSH), the uterus was resected at the level of the cervical isthmus. The uterine mass was extracted from the umbilical wound with morcellation using a knife. The cervical and vaginal stumps were sutured by laparoscopy using barbed suture V-Loc (Covidien) after LSH and laparoscopic total hysterectomy (LTH) were performed.

Statistical analysis

Data were expressed as mean ± standard deviation (SD) unless otherwise stated. Differences among the values between various surgical procedures were tested by Kruskal-Wallis one-way analysis of variance. We fitted the measured surgical times and some influencing factors on the surgery using a linear model estimated with generalized least squares. The model consisted of an orthogonal polynomial function for the learning curve, which is the additional surgical time with respect to surgical order of LESS surgery after the adjustment of the influential covariates. Specifically, the model is represented as:

$$\begin{aligned} Y_t = & \sum_{j=1}^{5} \alpha_{1j} \cdot I(Procedure_t = j) + \sum_{j=1}^{5} \alpha_{2j} \cdot I(Diagnosis_t = j) \\ & + \alpha_{31} \cdot EBL_t + \alpha_{32} \cdot EBL_t^2 \\ & + \sum_{j=0}^{1} \alpha_{4j} \cdot Adhesion_t \cdot I(Hysterectomy_t = j) \\ & + \sum_{j=0}^{1} \alpha_{5j} \cdot Size_t \cdot I(Hysterectomy_t = j) + f(t) + \varepsilon_t \end{aligned}$$

where Y_t is the surgical time for the t-th patient using LESS; *Procedure* and *Diagnosis* represents the five different types of surgical procedures and the six pathological diagnoses, respectively; the variable *EBL*, or log of blood loss centered by each procedure, is included for the purpose of model adjustment; *Adhesion* indicates the occurrence of pelvic adhesion; *Size* represents the adnexal diameter for adnexal surgery or the uterine weight for hysterectomy; $Hysterectomy = 0$ represents cases that underwent adnexal surgery; and $Hysterectomy = 1$ represents cases that underwent hysterectomy. The smooth function $f(t)$ is an orthogonal polynomial of degree 3 representing the learning curve. The error term ε_t is assumed to have an autoregressive process of order 2. The goodness-of-fit of the proposed model was evaluated by checking the R^2, residuals plot, normal quantile-quantile plot, and autocorrelation function plot. The statistical analysis was carried out using the Statistical Analysis System (SAS) version 8.0 (SAS Institute, Cary, NC, USA) and the free statistical software R (version 2.14.0). A p value < 0.05 was regarded as significant.

Results

A total of 63 women underwent LESS surgery during the study period. Two women with ovarian malignancies were converted to laparotomy and were excluded from the study. Frozen sections revealed serous ovarian adenocarcinoma in both patients. Three women, one in whom a gastrointestinal stromal tumor had been diagnosed, one who had received a laparoscopic myomectomy, and one who was simultaneously receiving hysteroscopic myomectomy surgery were also excluded from the study. Of the 58 women included, 39 underwent adnexal surgeries and 19 received hysterectomies. The mean age of women who underwent adnexal surgeries was younger compared with women who underwent hysterectomies (36.9 ± 10.3 years versus 45.0 ± 6.7 years; $p < 0.003$).

Demographic and surgical data for these two groups of women is given in Tables 1 and 2. Women who received unilateral or bilateral cystectomies were younger compared with women who received unilateral or bilateral salpingo-oophorectomies (USO/BSO). Cystectomy was preferable in diagnoses of endometriosis or dermoid cysts. The USO/BSO procedures caused substantially less blood loss and shorter surgical times compared with the cystectomy procedures. During hysterectomies, women who underwent LSH/LTH had substantially larger uterine weight and longer surgical time compared with women who underwent LAVH. No difference was found in the amount of blood loss between the two groups of women, though one woman who underwent LAVH required intraoperative blood transfusion.

Using exploratory data analysis, five factors were found to be potentially affecting surgical time for LESS surgery: the surgical procedure, diagnosis, EBL, pelvic adhesion, and tumor/uterine size. When surgical time was plotted against surgical order using a locally weighted regression model (as shown in Fig. 1), we found surgical time to be consistently stable in the adnexal surgeries. However, surgical time increased slightly with the increase of surgical order in hysterectomies.

The estimates and significance of these parameters determined by the linear model with generalized least squares methods are listed in Table 3. We found that mean surgical time positively correlated with the complexity of surgical procedures and estimated blood loss. More surgical time was required as the surgical procedure became more complicated. The most complicated LTH/LSH surgical procedure required the longest surgical time. The estimated mean surgical time in unilateral cystectomy was 10 minutes longer compared with USO/BSO and 23 minutes shorter compared with bilateral cystectomy after taking into account various factors, such as pelvic adhesion, EBL, ovarian size, and uterine weight. Hysterectomy through LAVH took 28 minutes longer than bilateral cystectomy, and TLH/LSH took 104 minutes longer than LAVH.

We also found that cases with endometriosis took 23 minutes longer than cases with other ovarian neoplasms, such as mucinous or serous cystadenoma. In adnexal surgery, the size of the dominant ovarian cyst was an independent factor influencing surgical time. The correlation between dominant size of ovarian cyst and surgical time is shown in Fig. 2. Pelvic adhesion, but not uterine weight, caused substantially longer surgical time in hysterectomies (Fig. 3). We have found no clear pattern in the residuals plots (not shown here). This demonstrated that the fitted model with $R^2 = 0.85$ satisfied the model assumptions. With the adjustment of these factors, the estimated learning curve of a polynomial function of degree 3 with 95% confidence limits, given in Fig. 4, revealed a flat curve ranged within 10 minutes along the surgical order. It

Table 2
Characteristics of women who underwent hysterectomy by laparoendoscopic single-site surgery.

	LAVH ($n = 14$)	LTH/LSH ($n = 5$)	p
Age (y/o)	45.3 ± 5.1 (38–57)	44.2 ± 10.6 (29–59)	0.75
BMI (kg/m^2)	24.0 ± 4.0 (17.9–32.0)	23.9 ± 5.5 (18.8–32.2)	0.66
Diagnosis			
Myoma/ adenomyosis	10	5	0.26
Uterine prolapsed	2	0	
Others[a]	2	0	
Previous surgical history	8 (57.1)	1 (20.0)	
Pelvic adhesion	6 (42.9)	2 (40.0)	
Uterine weight (g)	304.4 ± 162.5 (50–540)	552.2 ± 384.8 (150–984)	0.19
Estimated blood loss (mL)	172.1 ± 230.4 (10–900)	130.0 ± 103.7 (50–300)	0.96
Surgical time (min)	120.1 ± 28.6 (83–194)	205.6 ± 23.3 (187–246)	0.002
Hospital stay (days)	3.1 ± 0.3 (3–4)	3.0	0.47

Data are presented as n (%) or mean ± standard deviation (range).
*A p value was obtained using the Kruskal-Wallis rank sum test.
BMI = body mass index; LAVH = laparoscopic-assisted vaginal hysterectomy; LSH = laparoscopic subtotal hysterectomy; LTH = laparoscopic total hysterectomy.
Values are given as number (percentage) or mean ± standard deviation (range).
[a] One case of cervical cancer stage 1A1, 1 case of endometrial atypical hyperplasia.

Table 1
Characteristics of women who underwent adnexal surgery by laparoendoscopic single-site surgery.

	USO/BSO ($n = 12$)	Unilateral cystectomy ($n = 22$)	Bilateral cystectomy ($n = 5$)	p*
Age (y/o)	47.2 ± 9.1 (31–59)	32.4 ± 6.4 (20–44)	31.6 ± 9.2 (20–44)	<0.001
BMI (kg/m^2)	24.4 ± 5.6 (18.6–35.2)	21.4 ± 3.8 (17.3–35.1)	22.4 ± 3.8 (18.4–28.6)	0.27
Diagnosis				
Endometriotic cyst	1	10	4	0.17
Dermoid cyst	2	8	1	
Others[a]	9	4	0	
Previous surgical history	6 (50.0)	4 (18.2)	2 (40.0)	
Pelvic adhesion	3 (25.0)	7 (31.8)	2 (40.0)	
Ovarian dominant diameter (cm)	9.6 ± 4.7 (4–20)	6.6 ± 2.0 (4–12)	8.2 ± 5.7 (4–18)	0.11
Estimated blood loss (mL)	20.0 ± 18.8 (5–50)	13.5 ± 17.9 (3–80)	82.0 ± 73.3 (10–200)	0.01
Surgical time (min)	66.2 ± 26.9 (35–115)	73.0 ± 26.3 (40–144)	110.6 ± 51.1 (64–195)	0.07
Hospital stay (days)	2.1 ± 0.6 (2–4)	2.0	2.0	0.69

Data are presented as n (%) or mean ± standard deviation (range).
* A p value was obtained using the Kruskal-Wallis rank sum test.
BMI = body mass index; USO/BSO = unilateral salpingo-oophorectomy or bilateral salpingo-oophorectomy.
[a] Five cases of mucinous cystadenoma, four cases of serous cystadenoma, two cases of ovarian fibrothecoma, one case of paratubal cyst, one case of ovarian cancer for second-look surgery.

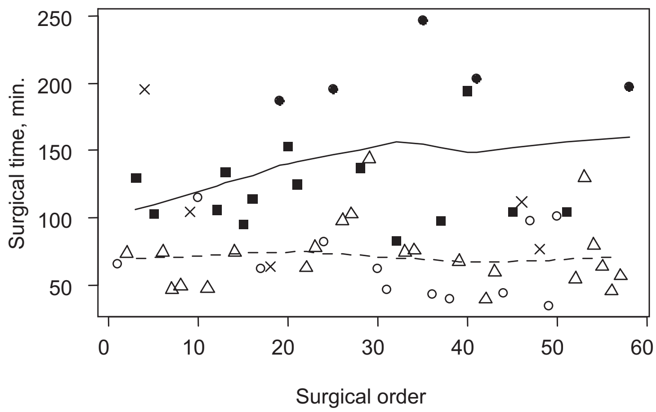

Fig. 1. Scatterplot of surgical time against surgical order in women receiving laparoendoscopic single-site (LESS) surgery. The curves depict the relationship between surgical time and surgical order using a locally weighted regression model in different LESS surgical procedures: broken line represents adnexal surgeries and unbroken line represents hysterectomies. Adnexal surgeries included unilateral salpingo-oophorectomy/bilateral salpingo-oophorectomy (circles), unilateral cystectomy (triangles), and bilateral cystectomy (crosses). Hysterectomies included laparoscopic-assisted vaginal hysterectomy (filled squares), laparoscopic total hysterectomy, and laparoscopic subtotal hysterectomy (filled circles). The correlations between surgical time and surgical order are 0.31 for hysterectomies and −0.18 for adnexal surgeries.

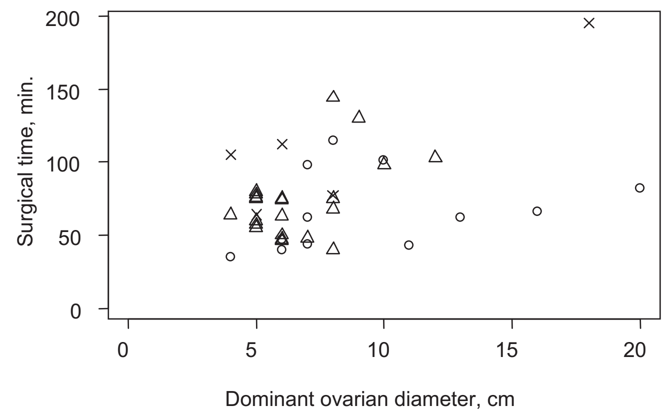

Fig. 2. Distribution of dominant ovarian diameter in ovarian surgeries: unilateral salpingo-oophorectomy/bilateral salpingo-oophorectomy (circles), unilateral cystectomies (triangles), and bilateral cystectomies (crosses) according to surgical procedures. The correlations between surgical time and dominant ovarian diameters are 0.27 for unilateral salpingo-oophorectomy/bilateral salpingo-oophorectomy, 0.50 for unilateral cystectomies, and 0.87 for bilateral cystectomies.

indicates that no learning curve of LESS surgery was identified from the surgeon.

Discussion

In our study of LESS surgery, all cases were managed successfully without the need for ancillary ports or conversion to laparotomy, except in two cases of incidental ovarian malignancy. Additional trocars were reported necessary in 1.1–11.1% of LESS surgeries.[9,18] Reasons for additional trocars were due to Stage IV endometriosis,[9] severe pelvic adhesion,[12] or large uterine size.[19] Although pelvic adhesion was found in 32.8% and uterine size >500 g in 26.3% of our cases, we insisted to finish LESS surgery without introducing additional trocars. Malignancy that required conversion to laparotomy during LESS adnexal surgeries was also encountered. The incidence was reported to be 2.1–4.2%.[8,12,13] This incidence is acceptable as compared to conventional multiport laparoscopic surgery.[20]

According to anticipated surgical volumes based on surgical experience, LESS surgeries have been used in both high- and low-volume procedures. Oophorectomy is categorized as a high-volume procedure, hysterectomy as an intermediate-volume procedure, and cystectomy and myomectomy as low-volume procedures.[1] Surgical volumes not only reflect surgical time but also difficulty of surgical technique. Our data showed that cystectomies, which require more surgical experience and are tabulated as a low-volume procedure, required more surgical time than oophorectomy. However, surgical time could be very different in procedures in similar volume categories. Hysterectomy through TLH/LSH, which is categorized as an intermediate-volume procedure, took almost 1.5 hours longer than LAVH, which also belongs to the intermediate-volume procedure category. Our data showed that surgical time was closely related to the complexity of surgical procedures.

Surgical time required from the beginning of performing different surgical procedures has been interpreted as a learning

Table 3
Linear regression analysis in predicting surgical time (minutes).

	α coefficient	SE	p
Surgical procedure			
USO/BSO	42.66	8.98	<0.001
Unilateral cystectomy	52.57	7.31	<0.001
Bilateral cystectomy	75.55	8.50	<0.001
LAVH	103.20	21.23	<0.001
LTH/LSH	207.74	25.33	<0.001
Diagnosis (vs. endometriotic cyst)			
Dermoid cyst	5.48	7.28	0.46
Other adnexal neoplasms[a]	−23.61	7.67	0.004
Myoma/adenomyosis	−12.08	21.29	0.57
Uterine prolapsed	−3.94	20.70	0.85
Others[b]	−9.20	15.90	0.57
Estimated blood loss (log scale, mL)			
EBL	17.31	3.15	<0.001
EBL × EBL	6.60	1.78	0.001
Adhesion			
In ovarian operation	0.59	5.59	0.92
In hysterectomy	33.90	9.50	0.001
Dominant ovarian size (cm)	3.29	0.70	<0.001
Uterine weight (g)	0.003	0.012	0.85

LAVH = laparoscopic-assisted vaginal hysterectomy; LSH = laparoscopic subtotal hysterectomy; LTH = laparoscopic total hysterectomy; SE = standard error; USO/BSO = unilateral salpingo-oophorectomy/bilateral salpingo-oophorectomy.

[a] Five cases of mucinous cystadenoma, four cases of serous cystadenoma, two cases of ovarian fibrothecoma, one case of paratubal cyst.

[b] One case of ovarian cancer for second-look surgery, one case of cervical cancer stage 1A1, one case of endometrial atypical hyperplasia.

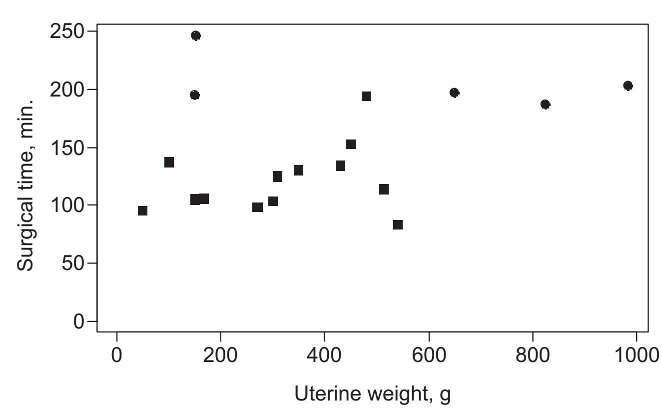

Fig. 3. Distribution of uterine weight in hysterectomies: laparoscopic-assisted vaginal hysterectomy (filled squares), laparoscopic total hysterectomy or laparoscopic subtotal hysterectomy (filled circles), according to surgical procedures.

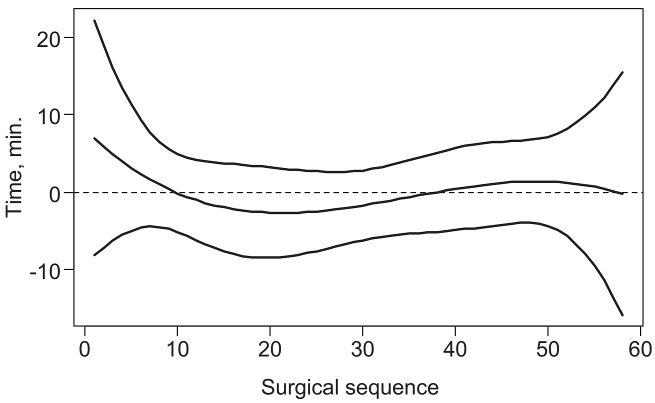

Fig. 4. The estimated smooth function of a learning curve with 95% confidence limits.

curve. Learning curve was required in the initial performance of conventional laparoscopic surgeries and 30 cases were reported necessary to reach a low level of complications.[21] Similarly, many studies have reported learning curves in their initial experience of LESS surgery. In simple surgeries such as LESS salpingo-oophorectomy, the number of cases performed was reported as the only factor influencing surgical time after controlling of factors such as previous abdominal surgery and BMI.[22] Surgical proficiency was achieved after 10–15 cases in salpingo-oophorectomy.[22] In more complicated surgeries such as LAVH, surgical time was found to be shorter after 10 cases[10] and proficiency was achieved after approximately 25 cases.[19] The learning curve is likely to be longer as the surgical procedure becomes more complicated. Paek et al[23] reported that proficiency was found in 40 cases in their constitutive series of 100 cases of TLH. However, most of these studies were based on one advanced laparoscopy surgeon's experience. To be precise, laparoscopic skills should be considered when the learning curve of a new surgical technique based on old established surgical skill was studied.[24] In addition, advanced surgeons were usually experiencing adnexal surgeries using LESS among their LESS hysterectomies. Therefore, both adnexal and hysterectomy LESS surgeries should be included when exploring the learning curve. In this study, we assessed the learning curve by including all of our initial cases of LESS surgeries, both the adnexal surgeries and the hysterectomies. In general, we found longer surgical time for more complicated surgical procedures. However, by using a generalized linear model for the adjustment of confounding factors, surgical order did not seem to influence surgical time. A learning curve was not found in our LESS surgery after adjustments for influencing factors on the surgical procedures were made.

One possible reason that a learning curve is not required in our LESS surgery is the bias of case selection. To shift from conventional multiport laparoscopy to LESS surgery, experienced laparoscopic surgeons generally start from simple, high-volume procedures to gain familiarity with the new technique.[11] The difficult, low-volume procedures are then introduced among the high-volume procedures, as the surgeon becomes more confident in handling the new surgical devices. When the surgeon becomes even more competent, the difficult procedures can become his or her dominant surgical procedure. In our study, we included all cases since our initial application of LESS surgery. It should be noted from the surgical order (as shown in Fig. 1) that difficult cases such as LTH and LSH were included in the latter half of our study. Consequently, this might result in no learning curve in LESS surgery for an advanced laparoscopy surgeon. However, it reflects the real situation in surgical practice.

We were also aware that while shifting from multiport laparoscopy to LESS surgery, many surgeons used additional trocars to compensate for the difficulty of LESS surgery.[8,9,13,18,19] This would cause difficulties in studying the true learning curve of LESS surgery. Therefore, we insisted on not using any additional trocars while facing cases with severe adhesion or with large pelvic masses, as long as surgical safety was assured. We could then reduce the bias of case selection to the lowest degree, and reflect the true learning curve of LESS surgery.

By using a locally weighted regression plot, surgical time for adnexal surgeries (as shown in Fig. 1) was found to be consistently stable throughout the study period. We found all three types of adnexal surgeries equally distributed throughout our study period. Cases with easier types of surgeries such as USO/BSO were larger in size and frequently more complicated in pathological findings than the other two types of adnexal surgeries (Table 1). More caution and surgical skill were required in handling these cases. Therefore, surgical time in these cases was not significantly shorter than the other two types of adnexal surgeries. In uterine surgeries, locally weighted regression plots show gradually increased surgical time throughout the order of surgery (Fig. 1). The increase in surgical time was due to the inclusion of more LTH/LSH during the latter half of our study period. Surgical time for LTH/LSH was significantly longer compared to that for LAVH and adnexal surgeries. However, only five cases of LTH/LSH were included in our study. More LTH/LSH and more equal distribution of these cases throughout the study period were required to have a better study of the learning curve for LESS hysterectomies.

Surgical time in the initial experience on conventional laparoscopic surgery was reported to reduce from 149 minutes to 125 minutes after 30 cases of cutoff proficiency.[21] Many studies have reported surgical times for LAVH and LTH/LSH using LESS surgery. In LESS hysterectomy, the average surgical time for LAVH was reported in the range of 64 minutes to 133 minutes[19,25,26] and the average surgical time for LTH was from 80 minutes to 100 minutes in uterine weights between 45 g and 482 g.[23,25] However, in cases with a uterine weight >500 g, surgical time for LAVH was found to be as high as 236 minutes and the failure rate was 15.4–23.8%.[27,28] We have previously formulated an equation to calculate the surgical time based on the surgical uterine weight in our initial experience of 225 cases of conventional LAVH. [17] Based on this formula, surgical time for our LESS hysterectomies were shorter than those of our initial cases of conventional LAVH. The observed shorter surgical time in our LESS hysterectomies could be due to the experience that we have obtained from our previous conventional LAVH. In addition, according to the generalized linear regression analysis, we did not find surgical time influenced by uterine weight in our study. However, uterine weight in the LTH/LSH group was slightly greater than that in the LAVH group, with an average greater than 500 g. Removal of such a heavy uterus from the 2–2.5 cm umbilical incision by morcellation with a knife required a longer period of time. In addition, LTH/LSH cases required a complete separation of the uterine body from the cervix or the vaginal stump using only straight instruments. These cases also required stump sutures, which is rather time consuming. In our past experiences, we had seldom performed LTH/LSH in multiport laparoscopic surgeries. Therefore, longer surgical time was required for LTH/LSH compared with the LAVH procedure.

In large adnexal tumors, LESS surgery is better than multiport laparoscopy in that it allows minilaparotomy through the umbilicus to remove cystic content without the risk of spillage of tumor contents.[29,30] In eight of our cases, the adnexal masses were >10 cm. Our data showed that there was an increase of only 3.3 minutes for every 1-cm increase in ovarian size. This could be due to the benefit of easier removal of cystic content and ovarian mass through the larger umbilical incision used in LESS surgery.

By using a fitted linear model, we found that surgical order had no influence on surgical time. In a locally weighted regression model, we also found no changes in surgical time in reference to the surgical order. This suggests that a learning curve is not required for LESS surgery. However, these results are based solely on a single advanced laparoscopic surgeon. In another recent study also performed by advanced laparoscopic surgeons, Song et al[31] reported the similar conclusion that a learning curve is not required in LESS oophorectomies, though they found a slight increase in surgical time and an increased requirement of additional ports in cystectomies. Many studies have compared LESS hysterectomies with multiport hysterectomies by experienced laparoscopic surgeons and reported that both types of surgery have similar surgical times.[25,26,32,33] These reports further support our findings that a learning curve is not required in LESS surgery for experienced laparoscopic surgeons. However, further studies of this nature would serve to strengthen our argument. A beginner of laparoscopic surgery might still find that a learning curve is necessary for LESS surgery.

In conclusion, we have determined that surgical time is related to the difficulty of the surgical procedure, not to the surgical order of LESS surgery in an experienced laparoscopic surgeon. More surgical time is required in cases with larger adnexal size, more pelvic adhesion during hysterectomy, more blood loss, and more complicated surgical procedures. We found LESS surgery to be safe and feasible. A learning curve is not necessary for experienced laparoscopic surgeons.

Conflicts of interest

The authors declare that they have no conflicts of interest or financial ties to disclose.

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