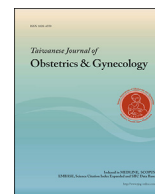




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Original Article

Uterine artery ligation at its origin following retroperitoneal space development decreases blood loss during single-port total laparoscopic hysterectomy

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ABSTRACT

Objective: This study aimed to determine risk factors associated with the failure of uterine artery ligation at its origin following development of the retroperitoneal space (UALr) and evaluated its efficacy in decreasing estimated blood loss (EBL) during single-port total laparoscopic hysterectomy (SP-TLH).

Materials and methods: This study includes patient data collected prospectively from May 1st, 2013 to establish a registry for single-port surgery. Data for the present study were collected retrospectively from May 1st, 2013 to August 30th, 2016. Patients who underwent SP-TLH for a symptomatic benign disease. When bilateral UALr was performed successfully, the case was classified as part of the UALr success group. When only unilateral UALr was completed or UALr failed, the case was classified as part of the failure group. We compared patients' baseline characteristics and surgical outcomes between the two groups.

Results: Bilateral UALr was successfully performed in 155 cases and failed in 64 patients. Body Mass Index (BMI) was significantly different between the two groups (24.1 kg/m² vs. 22.86 kg/m², $p = 0.025$). A BMI higher than 23.6 kg/m² was a risk factor for UALr failure in a multivariate analysis (odds ratio = 2.42, $p = 0.004$). EBL was significantly lower in the UALr success group compared to the UALr failure group (100 [100.0–200.0] vs. 200 [100.0–250.0], $p < 0.001$), and incidence of Hb decrease of more than 2 g/dl was higher in the UALr failure group (36.1% vs. 54.7%, $p = 0.017$).

Conclusion: We identified higher BMI as a risk factor for UALr failure and demonstrated the safety and efficacy of UALr in reducing blood loss during SP-TLH.

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Introduction

Minimally invasive surgery is a mainstay to treat benign gynecological disease. Minimally invasive surgery has great advantages in cosmesis, less pain, lower complication rates of bleeding and infection, shorter length of hospital stay, and faster return to normal activity [1].

Single-port laparoscopic surgery is growing in popularity with both patients and surgeons. Recent studies have demonstrated its feasibility, safety and superior cosmetic outcome for treatment of

benign disease of the uterus [2–4]. Among surgical procedures for benign gynecological disease, hysterectomy requires relatively more complex procedure than for ovaries such as securing vessels and dissection of uterus from adjacent organs.

Laparoscopic hysterectomies are divided into three categories depending on the method used to approach the uterine artery and vaginal component. One is laparoscopically assisted vaginal hysterectomy (LAVH), which divides the round ligament, and the utero-ovarian ligament or infundibulopelvic ligament laparoscopically. The uterine artery division and other component of surgical procedures are performed through the vagina. Another approach is laparoscopic hysterectomy (LH), which is ligation and division of uterine artery is performed laparoscopically, but part of operation performed vaginally. The other is a total laparoscopic hysterectomy (TLH), in which is performed all procedure including uterine artery ligation laparoscopically. In LAVH, the uterine artery

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is ligated alongside the uterus at the level of the internal cervical orifice through the vagina. In TLH or LH, the uterine artery can be ligated alongside the uterine cervix or at its' origin from the internal iliac artery.

Uterine artery ligation alongside uterine cervix is more susceptible to bleeding especially under setting of single-port total laparoscopic hysterectomy (SP-TLH) due to the angle of approach to the vessel [5]. With umbilical approach of SP-TLH, uterine artery coagulation is performed after contralateral traction of uterus, and the approaching angle to the uterine artery is not perpendicular to the artery laparoscopically. Incomplete sealing of uterine artery may lead to bleeding and excess coagulation may result in ureteral injury [5]. Furthermore, enlarged uterus with myoma or adenomyosis has well-developed vascular supply and the vessel is very tortuous around the uterine cervix. In contrast to the alongside uterine artery ligation, the angle to the uterine artery in retroperitoneal approach is almost perpendicular to the vessel in SP-TLH [5]. In the previous study, uterine artery ligation at its origin following retroperitoneal space development (UALr) was effective in reducing operation time and EBL in SP-TLH comparing to the alongside ligation of uterine artery [6]. This approach to uterine vessel during SP-TLH may be particularly beneficial when a patient requires minimal blood loss or has uterus with severely distorted shape. However, considering the complexity of the technique and the limited actionable surgical range of motion of SP laparoscopy, this technique may not be successful in all cases.

In this study, we aimed to determine risk factors for UALr failure and evaluate potential consequences of UALr failure by evaluating EBL and perioperative complications of SP-TLH.

Materials and methods

Patient enrollment

We collected patients' data prospectively since May 1st, 2013 to establish a registry for SP surgery performed by one surgeon (TJ Kim of Samsung Medical Center) after obtaining informed consent. This study was approved by the Samsung Medical Center Institutional Review Board (IRB No: 2013-02-029). We retrospectively reviewed the registry for the present study. We enrolled patients who had an elective SP-TLH for treatment of a symptomatic benign disease such as myoma, adenomyosis or endometrial polyp in the study. Once a patient had anemia resulted from abnormal uterine bleeding, the patient was administered oral iron or intravenous iron with a suggestion of adequate therapy according to the cause of abnormal uterine bleeding such as oral contraceptives, NSAID or Mirena®. When a patient decided to undertake surgery, the patient was adequately treated for the anemia with iron or transfusion preoperatively to get around 10 g/dL of hemoglobin level. We excluded patients for which UAL location was not recorded.

Data collection

Data were collected retrospectively from May 1st, 2013 to 30th August 2016. We collected data for demographic information, uterine size, operative indication, additional procedures, estimated blood loss (EBL), uterine weight, change in hemoglobin (Hb) level, UALr failure, the reason for UALr failure, length of postoperative hospital stay, intraoperative and postoperative complications, and final pathology assessments. Uterine diameter was measured longitudinally and anterior-posteriorly before surgery by transvaginal ultrasonography, computed tomography or magnetic resonance imaging. The operative time was measured for each step as described previously [5]. We collected total operative time, vascular clamping time (Scope I) and uterus separation time (Scope

II). Total operative time was defined as the time from the beginning of the skin incision to the completion of skin closure. The vascular clamping time included ligation of the utero-ovarian ligament (or the infundibulopelvic (IP) ligament), round ligament, and uterine artery (alongside the cervix and by retroperitoneal access), as well as a detachment of the bladder. The uterus separation time included detachment of the uterosacral and cardinal ligaments, vaginal cutting, and uterus removal. Blood loss was estimated by subtracting the irrigation fluid volume from the total amount of fluid in the suction apparatus and the number of gauzes used. Hemoglobin level was evaluated preoperatively and on postoperative Day 1. Hemoglobin (Hb) change was calculated by subtracting postoperative Hb from preoperative Hb.

The SP-TLH procedure

The SP-TLH surgical procedure was described in a previous study [5]. The first step of SP-TLH was an interruption of vascular supply to the uterus. In this step, UALr was attempted in all cases. Briefly, the retroperitoneal space was developed by opening the retroperitoneal space along the common iliac artery. After identifying the ureter at the level of the pelvic brim, further dissection lateral to the ureter was performed to identify the internal iliac artery. Skeletonizing the uterine artery was begun where the uterine artery crosses over the ureter. Finally, the uterine artery was coagulated or transected at its origin (Fig. 1). After ligation of the uterine artery through the retroperitoneal approach, the remaining procedures of SP-TLH were performed as previously described. When UALr failed, the uterine artery was ligated alongside the uterine cervix at the level of the endocervix. When bilateral UALr was performed successfully, the case was classified into the UALr success group. When only unilateral UALr was completed or UALr failed the case was classified into the failure group.

Statistical analyses

Continuous variables were compared using the Mann–Whitney U test or Student's t-test. Fisher's exact test and the χ^2 test were used for categorical variables. A multivariate logistic regression model was utilized to identify risk factors for UALr failure. All results refer to 2-tailed tests, and *p*-values under 0.05 were considered statistically significant. Data were analyzed using the R statistical software package (version 3.3.2 for Mac).

Results

Two hundred and fifty-seven patients underwent SP-H for a symptomatic benign disease at the Department of Gynecology in Samsung Medical Center in Seoul, Korea between May 1st, 2013 and August 31st, 2016. There were two hundred fifty-two cases of SP-TLH and five of SP-LAVH. Two hundred and nineteen patients who had an SP-TLH with a record of UAL location were included for analysis. Bilateral UALr was successfully performed in 155 cases (the UALr success group) and failed in 64 cases (the UALr failure group). In the UALr failure group, the UALr failed unilaterally in 19 patients and bilaterally in 45 patients (Fig. 2). Six patients received transfusion with 1 or 2 unit of packed red blood cell before checking preoperative Hb. Therefore, no one showed less than 8 g/dL of hemoglobin preoperatively.

There were no cases of conversion to laparotomy or additional ports for laparoscopy. We compared patient characteristics between the UALr success group and the UALr failure group to determine predictors of failure for UALr. Of the patient data assessed, only BMI was significantly different between the two groups (24.1 vs 22.8, *p* = 0.025) (Table 1). A 23.6 kg/m² or higher of

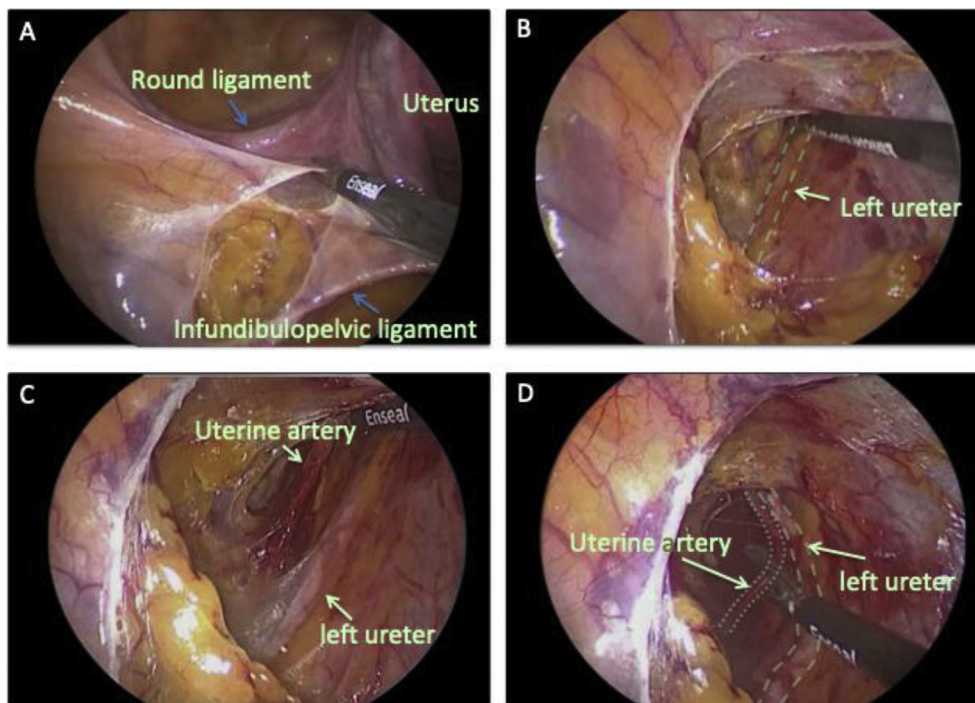


Fig. 1. Uterine artery ligation by the retroperitoneal approach, left side. (A) Traction of the infundibulopelvic ligament medially and opening of an anterior leaf of the broad ligament. (B) Dissecting lateral to the ureter and following it anteriorly. (C) Development of the pararectal and paravesical space (Step 6). (D) Skeletonizing the uterine artery where it originates from the internal iliac artery and ligate of the uterine artery at its origin with an advanced bipolar device.

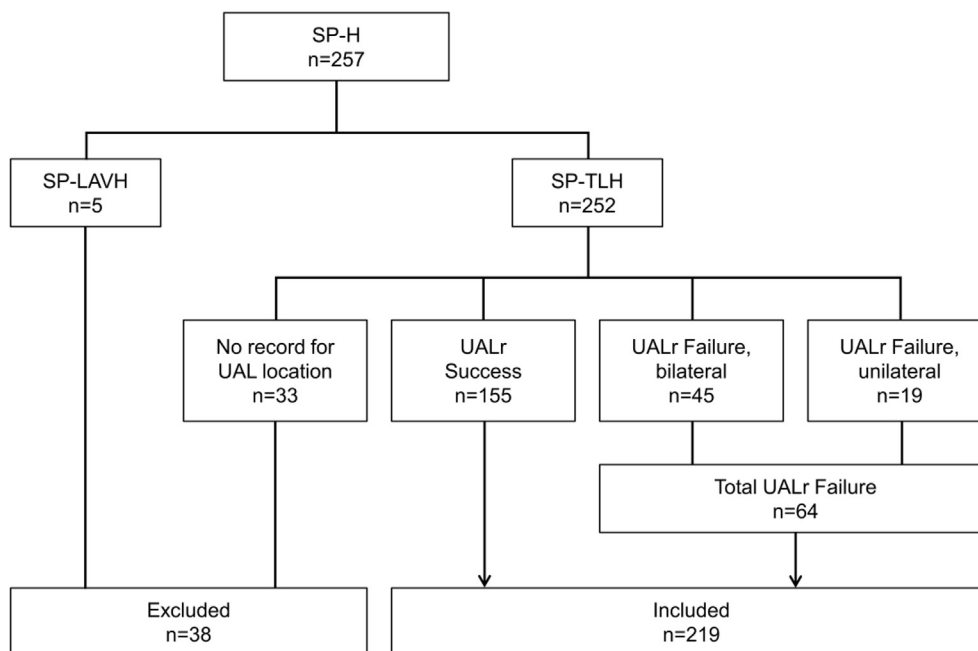


Fig. 2. Flow chart for the study design. 257 SP-H cases were identified. Five SP-LAVH cases, were excluded. UAL location was recorded in 219 patients. UAL was successfully performed bilaterally in 155 patients. In 64 patients, an attempted UAL resulted in failure. In the failure cases, the UAL failed unilaterally in 19 cases and bilaterally in 45 cases. SP-H: single port laparoscopic hysterectomy SP-LAVH: single port laparoscopically assisted vaginal hysterectomy SP-TLH: single port total laparoscopic hysterectomy UAL: uterine artery ligation UALr: uterine artery ligation at its origin following development of the retroperitoneal space.

BMI was a risk factor for UALr failure in a multivariate analysis (Table 2).

Additional procedures performed were comparable between the two groups, and opportunistic salpingectomy or salpingo-oophorectomy was the most commonly performed procedures in addition to the hysterectomy (Table 1).

When surgical outcomes were compared, there were no differences between uterine weight, hemoglobin change, or the length of postoperative hospital stay. However, EBL was significantly greater in the UALr failure group compared to the UALr success group, and patients in the UALr failure group had a higher incidence of Hb decreasing 2 g/dl or more (Table 3).

Table 1
Patient characteristics.

	UALr Success (n = 155)	UALr Failure (n = 64)	P-value
Age, median [IQR]	45.0 [42.0–48.0]	46.0 [42.5–48.0]	0.613
BMI, median [IQR]	22.8 [21.2–25.0]	24.1 [22.1–25.8]	0.025*
Preoperative hemoglobin	12.6 [11.3; 13.2]	12.6 [11.4; 13.4]	0.382
Preoperative transfusion, n (%)	4 (2.6%)	2 (3.1%)	1.000
Uterine length ^a	9.7 [8.5–10.9]	9.9 [8.5–11.1]	0.455
Uterine AP dimension ^a	6.6 [5.3–8.0]	7.1 [5.5–8.1]	0.357
Main symptom/reason for surgery ^b , n (%)			
Dysmenorrhea	36 (23.2%)	16 (25.0%)	0.916
Vaginal bleeding	86 (55.5%)	34 (53.1%)	0.865
Pelvic pressure or pain	36 (23.2%)	8 (12.5%)	0.307
Palpable mass	13 (8.4%)	7 (10.9%)	0.735
Increased size	9 (5.8%)	1 (1.6%)	0.311
Urinary symptom	20 (12.9%)	4 (6.2%)	0.232
Lower back pain	5 (3.2%)	1 (1.6%)	0.818
Parity, n (%)			0.283
0	10 (6.5%)	8 (12.5%)	
1	37 (23.9%)	13 (20.3%)	
2	98 (63.2%)	35 (54.7%)	
3	8 (5.2%)	7 (10.9%)	
4	2 (1.3%)	1 (1.6%)	
History of vaginal delivery, n (%)	99 (63.9%)	37 (57.8%)	0.492
Number of previous abdominal operation, n (%)			0.630
0	83 (53.5%)	39 (60.9%)	
1	35 (22.6%)	9 (14.1%)	
2	30 (19.4%)	12 (18.8%)	
3	6 (3.9%)	3 (4.7%)	
4	1 (0.6%)	1 (1.6%)	
Additional procedure, n (%)			
None	7 (4.5%)	1 (1.6%)	0.507
Opportunistic adnexectomy ^c	145 (93.5%)	61 (95.3%)	0.851
Surgery for adenexa ^d	25 (16.1%)	7 (10.9%)	0.436
Posterior colporrhaphy	3 (1.9%)	1 (1.6%)	1.000
Trans-obturator tape operation	2 (1.3%)	1 (1.6%)	1.000
Omentectomy	2 (1.3%)	1 (1.6%)	1.000
Adhesiolysis	65 (41.9%)	21 (32.8%)	0.269

UALr, uterine artery ligation at its origin following development of the retroperitoneal space.

BMI = Body mass index (kg/m²); IQR = interquartile range.^a Uterine length was measured on a midline sagittal image from the tip of the serosal surface of the fundus to the distal aspect of the cervix (the external os). The AP dimension of the uterus was measured on the same sagittal image from its outer anterior to outer posterior wall, in a plane perpendicular to the longitudinal axis.^b 69 patients had more than 1 main symptom and/or reason for surgery.^c Opportunistic adnexectomy refers to salpingectomy or salpingo-oophorectomy without any pathological symptoms in either adnexa. Salpingectomy or salpingo-oophorectomy were performed for normal adnexa per the patient's request.^d Surgery for adenexa refers to adnexal surgery for adnexal pathologic finding.

We investigated the incidence for transfusion, other organ injuries, and prolonged the length of postoperative hospital stay as perioperative complications (Table 3). There were three cases of transfusion postoperatively. One patient in the UALr success group received 2 units of red blood cells to treat low post-operative Hb of 7.7 g/dl (Preoperative hemoglobin was 10.3 g/dl). In the UALr failure

group, one patient went from 9.5 g/dl of hemoglobin down to 7.0 g/dl, and the other patient decreased from 10.0 g/dl Hb to 7.3 g/dl.

There was one case of injury to other organs in the UALr failure group. This patient failed UALr because of an enlarged uterus and required a bladder primary repair due to bladder injury.

Operative times are presented in Table 4. The total operative time and the uterus separation time were comparable between the two groups. The vascular clamping time was longer in the UALr success group than in the UALr failure group (7 min vs. 5.0 min; $p < 0.001$).

We collected additional data to identify risk factors of UALr failure (Table 5). 48 cases reported the reason for UALr failure, which included myoma, adhesion, bleeding during space development, and device error. The majority of the UALr failure cases were caused by an obscured approach to the retroperitoneal space due to an enlarged uterus or myomas. Specifically, 31 out of 48 cases failed due to an enlarged uterus by myoma or adenomyosis. Of note, right side failure was more common than left side failure when UALr was successful on only one side.

Discussion

We found that UALr can be safely attempted to reduce blood loss during SP-TLH. We report that BMI was higher in the UALr failure

Table 2
Multivariate analyses of preoperative risk factors for failure of uterine artery ligation at its origin after retroperitoneal space development.

Variables	Odds ratios	95% CI	p-value
Main Diagnosis			
Myoma			
Other than Myoma	0.98	0.52–1.83	0.947
History of vaginal delivery			
Yes			
No	0.70	0.37–1.30	0.254
Adhesion			
Yes			
No	0.66	3.34–1.23	0.193
BMI			
BMI<23.6			
BMI≥23.6	2.42	1.33–4.46	0.004*

BMI = Body mass index (kg/m²).

Table 3
Surgical outcomes.

	UALr Success (n = 155)	UALr Failure (n = 64)	p-value
Weight of uterus (g), median [IQR]	300.0 [208.0–434.0]	310.0 [204.0–484.0]	0.627
EBL ^a (ml), median [IQR]	100.0 [100.0–200.0]	200.0 [100.0–250.0]	<0.001*
Hemoglobin change ^b (g/dl), median [IQR]	1.7 [1.1–2.3]	2.0 [1.1–2.5]	0.236
Hemoglobin change ≥ 2 g/dl, n (%)	56 (36.1%)	35 (54.7%)	0.017*
Adhesiolysis, n (%)	38 (24.5%)	16 (25.0%)	1.000
Main Diagnosis (pathology) n (%)			0.410
Adenomyosis	56 (36.1%)	22 (34.4%)	
Myoma	98 (63.2%)	40 (62.5%)	
Cervicitis	1 (0.6%)	1 (1.6%)	
Endometrial polyp	0 (0.0%)	1 (1.6%)	
Perioperative complication, n (%)			
Other organ injury	0 (0%)	1 (1.6%)	0.647
Transfusion (%)	2 (1.3%)	1 (1.6%)	1.000
Prolonged the length of postoperative hospital stay (>4 days)	5 (3.2%)	3 (4.7%)	0.898

UALr = uterine artery ligation at its origin following development of the retroperitoneal space.

IQR = interquartile range; EBL = Estimated blood loss.

^a EBL was calculated by subtracting the irrigation fluid volume from the total amount of fluid in the suction apparatus and the used number of gauzes.^b Hemoglobin (Hb) change was calculated by subtracting postoperative Hb from preoperative Hb.**Table 4**
Operative time.

	UALr Success (n = 155)	UALr Failure (n = 64)	p-value
Total operative time ^a (minutes), median [IQR]	90.0 [78.0–115.5]	91.5 [77.5–121.0]	0.922
Vascular clamping time ^b (minute), median [IQR]	7.0 [5.0–12.0]	5.0 [2.0–5.2]	<0.001*
Uterus separation time ^c (minute), median [IQR]	10.0 [6.0–17.0]	10.0 [6.0–19.0]	0.802

UALr = Uterine artery ligation at its origin after retroperitoneal space developing; IQR = interquartile range.

^a Total operative time was evaluated in 219 patients. Total operative time was defined as the time from the beginning of the skin incision to the completion of skin closure.^b Vascular clamping time was evaluated in 172 patients. The vascular clamping time included ligation of the utero-ovarian ligament (or infundibulopelvic (IP) ligament), round ligament, and uterine artery (alongside the cervix or retroperitoneal access), as well as detachment of the bladder.^c Uterus separation time was evaluated in 206 patients. The uterus separation time included detachment of the uterosacral and cardinal ligaments, vaginal cutting and uterus removal.

group, and BMI was the only identifiable preoperative characteristic assessed in this study that affected the UALr success rate (Table 1). Therefore, BMI could be used to predict the potential success of UALr. UALr failure was not associated with perioperative complications but was associated with EBL and Hb change (Table 3).

Anemia is associated with significant morbidity and mortality [7]. In the past, the mainstay of anemia treatment was allogenic blood transfusion. As evidences has been cumulated, allogenic blood transfusion was identified as an independent risk factor for poor clinical outcomes [8]. The Society for the Advancement of Blood management defined Patient Blood Management (PBM). PBM is consisted of three pillars; the optimization of RBC mass, reduction of blood loss and bleeding, and optimization of the

patient's physiological tolerance toward anemia [9]. Enrolled patients were symptomatic, and the main symptom was abnormal vaginal bleeding. To decrease anemia and transfusions during perioperative period, 97.3% of patients (213/219) had adequately treated for the anemia with intravenous or oral iron, and only 6 patients received transfusion with one or 2 unit of packed red blood cell. As a result of adequate preoperative management of anemia, all patients showed higher than 8 g/dL of hemoglobin after preoperative blood test without transfusion. According to the transfusion guideline published by World Health Organization, the Hb level of transfusion trigger is 8 g/dL. It suggests that intra- or postoperative transfusion may be avoided in patients with symptomatic myoma or adenomyosis if the bleeding is minimized by adequate surgical procedure during surgery with adequate preoperative management for anemia.

A higher BMI is related to complexity in gynecologic laparoscopy because of increased difficulties in identification of important anatomical landmark [10]. SP-TLH by UALr requires identification of several important anatomical landmarks such as internal iliac artery, ureter, and the location of bifurcation of uterine artery. In the present study, success rate of SP-TLH by UALr was significantly different whether a BMI was less than 23.6 kg/m² or not. The BMI of 23.6 kg/m² is not in obviously obese range. However, BMI of 23.6 kg/m² is categorized as the pre-obesity stage in the Korean population [11]. In the Korean population, BMI between 23 kg/m² and 24.9 kg/m² was defined as pre-obesity stage due to the increased morbidity. It is likely that the complexity of the surgical procedure and the risk of bleeding increase in pre-obese and obese individuals. Therefore, if patient's BMI is pre-obesity stage or higher than that, clinicians should pay more attention to normalize Hb for the higher bleeding risk in UALr failure case during surgery.

Table 5
Described causes for failure of UAL at its origin following retroperitoneal space development.

UALr failure side	Left (n = 6)	Right (n = 13)	Both (n = 45)	Total (n = 64)
Enlarged uterus by Myoma ^a	2	6	12	20
Enlarged uterus ^b	1	1	9	11
Adhesion	1	2	9	12
Bleeding during space development	1	1	1	3
Device error			1	1
Only one side attempted	1	0	0	1
No record	0	3	13	16

UALr failure: uterine artery ligation alongside the uterine cervix due to failure of UAL at its origin.

^a Distorted uterus by myoma or the location of myoma obscured surgical field approach to uterine artery.^b Enlarged uterus without protruding myoma or shape distortion of uterus.

The opportunistic adnexectomy was the most commonly performed additional procedure during SP-TLH in this study (Table 1). The SGO Clinical Practice Statement now recommends that salpingectomy should be considered at the time of hysterectomy to reduce the risk of ovarian cancer, so the incidence of opportunistic salpingectomy or salpingo-oophorectomy has considerably increased. Specifically, in a previous report, the incidence of opportunistic salpingo-oophorectomy was 68.1% (49/72) during SP-TLH [6]. In the present study, 94.1% of cases also had opportunistic salpingectomy performed, and there were no surgical complications such as operative bleeding, other organ injury, prolongation of operative time, prolongation length of hospital stay. Therefore, the opportunistic salpingectomy can be safely performed during SP-TLH without surgical complication.

This study showed that UALr could help to reduce major complications of SP-TLH such as urinary tract injury and major bleeding. In this study, there were only four cases of major complication (1.8%), including one case of bladder injury and three cases of transfusion. The case of bladder injury was identified during surgery, and repaired laparoscopically. The injury was occurred at the dense adhesion site formed by previous cesarean section during separation of bladder from uterus. No incidences of ureter injury during SP-TLH were reported. Urinary tract injury is identified intraoperatively in very low rate. According to the results of a retrospective Canadian national registry study, only 18% of urinary tract injuries were identified during surgery. The FINHYST study similarly reported a low rate of identification for ureter injury during surgery [12]. When ureter injury did occur, the cardinal ligament where the ureter passes inferior to the uterine vessels was the most commonly injured location [13]. During conventional SP-TLH, diathermy is used around this area to secure the uterine artery and to separate the uterus. When the uterine vessels bleed at this location, particularly during uterine artery securing, excessive diathermy results in urinary tract thermal injury near the uterine artery. The complication of thermal injury is frequently identified in several days from injury because thermal injury may not result in immediate rupture or stricture of urinary tract. Therefore, not to apply excessive diathermy round uterine cervix is essential to prevent ureter or bladder injury.

Furthermore, EBL was significantly lower in the UALr success group compared to the UALr failure group. When both uterine arteries are ligated at their origin, blood flow to the uterus is considerably decreased and induces ischemia. As the uterine blood flow is decreased, blood loss decreases during dividing uterus from tissues around uterus such as utero-ovarian vessel, cardinal ligament and vagina. After UALr, the uterine artery is ligated again alongside the uterine cervix during uterus separation. It means one practical role of UALr may be to facilitate UAL ligation alongside the uterus, contributing to decreased blood loss. Previously reported study showed similar results with the present study that dissection and ligation of the uterine arteries at their origin helped to reduce the blood supply and also lowered the risk of thermal ureteral injury [14,15]. Therefore, UALr may be a good option to decrease EBL in patients who refuse transfusion during hysterectomy.

Although advantages of the UALr to reduce bleeding, UALr was not always successful. The failure rate was 29% (64/219). According to the medical record, the main reason for the UALr failure was attributed to the enlarged or distorted shape of uterus. The uterus weighs in at 50 g–60 g normally. The median of uterus in this study was 300 g [208.0–434.0] in UALr success group, and 310 g [204.0–484.0] in UALr failure group. It means that the uterus was much bigger than normal because we enrolled patient who had adenomyosis or myoma with symptoms. Almost of the uterus with myoma or adenomyosis usually has distorted the asymmetric shape. UALr is difficult in some cases depending on the size or

location of uterus. Especially, when large myoma is located at laterally, contralateral traction of uterus is not sufficient to develop retroperitoneal space. In obese women, volume of fat tissue at abdominal wall and intestine is larger than skinny patients that decrease space to operation. Combination of limited space due to fat tissue and enlarged uterus confines movability of uterus and space approaching to the retroperitoneal space. In addition to this, fat tissues in the retroperitoneal space hinders identifying key structure such as internal iliac artery or uterine artery, and dissection of soft tissue around ureter or vessels make bleeding easier than skinny women. The enough peritoneal space and movability of myoma is important to accomplish UALr. But, obese persons frequently have small space and unclear anatomical key structure. When the retroperitoneal space was getting wet or taking longer time to accomplish UALr than we expected during dissection of fat tissue to identify uterine artery, UALr procedure was abandoned by the surgeon since the purpose of the UALr is to reduce intraoperative bleeding and save operation time. Abandon of UALr would be major reasons of no record for the cause of UAL failure.

In this study, we found several differences compared with previously reported operative outcomes of UALr. In the present study, total operative time was comparable between groups regardless of UALr success or failure. However, a previous study reported that UALr resulted in shorter total operative time compared to a conventional SP-TLH group in which UAL was performed alongside the cervix; SP-aH. It is possible that this discordance between the two studies is due to the study design, as the control group in the previous study was a historical control group and SP-aH surgeries were performed prior to SP-TLH with UALr. Therefore, SP-TLH with UALr was performed after the surgeon was already proficient in SP-TLH through previously performing SP-aH surgeries. In this study, SP-TLH surgeries in the UALr failure group were performed during the same period as the successful UALr surgeries instead of using a historical control group [6]. Additionally, when comparing total operative time between the UALr groups in the two studies, although the vascular clamping time decreased from 27.5 min to around 7 min in our study, the total operative time was increased to 90.0 min in the present our study compared 75 min in the previous study. The increased operative time of SP-TLH with UALr in our study may be a result of a different morcellation method for uterus removal and a different method to calculate total operative time. Since 2014, our surgeon has removed the uterus using knife morcellation by hand in the laparoscopic pouch instead of intra-peritoneal morcellation using a power morcellator. Another possible reason for the increased operative time of this study is that we used real-time operating room data, in which the total operative time includes preparation time for all steps, such as time for gauze counting before skin closure. In the previous study, the total operative time was calculated by the sum of each step and excluded waiting time for preparation between steps.

Major limitations of this observational study include the use of non-randomized study and missing data for operative time or the reason for UALr failure. A randomized controlled trial would be ideal to validate the beneficial effect of UALr at its origin following retroperitoneal space development. Since we reported the beneficial effect of decreasing EBL with the use of UALr in a previous study [6], UALr has been routinely performed. Because data was collected in the SP registry after the initiation of performing UALr routinely in SP-TLH since 2013. Therefore, the study design could not be randomized controlled study. Additionally, although the registry for SP was planned prospectively, not all data for each step were recorded. Missing data might be one of the reasons for discordant results for operative time compared to the previous study. Another weakness of the present study is that even though we identified increased EBL

in the UALr failure group, we were unable to suggest methods to decrease EBL upon UALr failure.

Overall, we demonstrated that BMI could be used to predict the potential success of UALr, and additionally the safety and efficacy of UALr in reducing blood loss during SP-TLH. The effect of UALr in reducing the amount of bleeding is consistent with previous studies.

UALr has a reduction in bleeding compared to the alongside uterine artery ligation [6]. Despite the usefulness of UALr, this treatment is not always successful, so we want to find out factors of failure, find out the negative consequences of failure, and find out what appropriate treatment will be available to minimize the adverse consequences. According to results in our study, the probability of failure increased if the BMI was 23.6 kg/m² or higher, and the amount of blood loss as a result of failure increased. Therefore, it is advantageous for patients with a high probability of failure to receive intensive treatment for anemia before surgery to reduce blood transfusions. These efforts through preoperative to the intraoperative stage will help reduce perioperative complications caused by anemia and blood transfusion.

Declaration of Competing Interest

The author(s) have no conflicts of interest relevant to this article.

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