The Efficacy of Gasless Reduced-port Laparoscopic Surgery for Gynecological Diseases

Hiroe Ito

Tokyo Medical University Hospital

Junya Kojima

Tokyo Medical University Hospital

Yasukazu Sagawa

Tokyo Medical University Hospital

Tomoyoshi Akaeda

Akaeda Clinic

Keiichi Isaka (✉ isaka@ohor-hosp.jp)

Tokyo International Ohori Hospital

Research Article

Keywords: gasless laparoscopic surgery, subcutaneous abdominal wall lifting, reduced-port surgery, gynecological diseases

Posted Date: September 27th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-785600/v1>

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Abstract

Objective

The purpose of this study was to examine the effectiveness of gasless reduced-port laparoscopic surgery (GRP-LS) using a 5 mm endoscopic port and one surgical port for the treatment of gynecological diseases

Methods

We compared GRP-LS and gasless 3-port laparoscopic surgery (G3P-LS), based on patient background, operative procedures, number of surgeries performed by the surgeon, length of surgery, blood loss, blood transfusion, conversion rate to open surgery, operative complications, and the number of surgeons involved in the procedure. We compared the two techniques in patients being treated for laparoscopic myomectomy (LM), laparoscopic ovarian cystectomy (LC), and laparoscopic salpingectomy (LT).

Results

GRP-LS was used in 2,338 cases and G3P-LS in 2,473 cases. GRP-LS was used in 980 LM cases (41.9%); 804 LC cases (34.4%); 240 LT cases (10.3%); 180 LA cases (7.7%); and 134 cases for other conditions (5.7%). GRP-LS was used by 78 surgeons; 85.9% of the surgeons had performed fewer than 50 GRP-LS surgeries in their careers; and those surgeons performed about half of all surgeries. The time required for GRP-LS was significantly less for LM, LC, LT, and the procedure also had less blood loss for LM and LC than G3P-LS. G3P-LS required a transition to open surgery in 0.69% of cases, whereas GRP-LS showed a very low rate of 0.09%.

Conclusions

GRP-LS is a new type of laparoscopic surgery that has overcome disadvantages of the previous lifting methods (G3P-LS) and is easier to learn, allowing inexperienced laparoscopic surgeons to effectively perform the surgery.

Introduction

Laparoscopic surgery (LS) is minimally invasive compared to conventional open surgery, and patients benefit from a faster and less painful recovery period. For surgeons, however, laparoscopy is more technically challenging, and a lengthy training period is required to perform a safe and effective surgery. To improve surgical safety and overcome some of these technical obstacles, we have introduced the abdominal wall lifting method (AWL).

We initially performed LS with the pneumoperitoneum method, which involves inflating the abdominal area using carbon dioxide (CO₂), but since we experienced serious complications in the early stages of LS, we sought a safer method. As a result, we introduced the subcutaneous AWL method (SAWL) in 1993. SAWL and a similar technique, the abdominal wall full-layer lifting method, are gasless procedures that do not use CO₂ insufflation. SAWL lifts the abdominal wall by inserting a steel wire under the skin, which creates and secures an operative field in the abdominal cavity. SAWL was first reported by Nagai and Hashimoto in 1991^{1,2}; the abdominal wall full-layer lifting method was reported by Gazayerli in 1991³; and the device developed by Newman et al. in 1993⁴ was later sold under the product name of Laparolift (Origin Med systems, Menlo Park, CA).

The full-layer lifting method provides a relatively good operative field because the lifting device is inserted directly into the abdominal cavity, but once the abdominal wall is lifted, it is difficult to lower the abdominal wall and lift again during the surgery. On the other hand, SAWL has advantages such as that there is no risk of damaging the intestinal tract when inserting the lifting device and the ability to freely lower and raise the abdominal wall when removing an ovarian tumor.

We were the first to use SAWL in gynecologic surgery⁵, performing the procedure with relatively thick steel wires (5 mm) to lift the abdominal wall at two points. This gasless three-port laparoscopic surgery (G3P-LS) was safe, provided a good exposure of the operative field, and was less expensive for the patient. On the other hand, this technique initially had drawbacks, including the long preparation time required to set the steel wire. In addition, the use of forceps is limited by the intrusion of the lifting bars (Fig. 1-A). Since the time of first use, however, we have made improvements such as reducing the diameter of the steel wire (1.2 mm)⁶ (Fig. 1-B), discontinuing the use of sheaths for the forceps, introducing the Lap Protector® (Hakko Co., Ltd., Nagano, Japan)⁷, using a 5 mm laparoscope, and changing the methods for installing the ports. These changes have resulted in gasless reduced-port laparoscopic surgery (GRP-LS), which uses only one surgical port (Fig. 1-C).

In this study, we examine the efficacy of GRP-LS for gynecologic diseases, using a 5 mm endoscopic port and one surgical port.

Materials And Methods

1. Surgeries and surgical methods

We retrospectively studied patients who underwent gasless laparoscopic surgery (GLS) at our hospital between September 1993 and December 2016. The data collection method was approved by the Institutional Review Board of Tokyo Medical University (Approval number: T2020-0089), and written informed consents had been obtained from all the included patients.

The GRS-LS technique currently in use was introduced in September 2005. During this transition period, G3P-LS, gasless two-port laparoscopic surgery (G2P-LS), and gasless single-port laparoscopic surgery

(GSP-LS) have been performed (Fig. 2). In this study, we compare GRP-LS, the technique most commonly used today, with G3P-LS, the technique used at the beginning of GLS.

2. Preoperative preparation and basic procedures for GRP-LS

1) Preoperative preparation

The patients were given general anesthesia, put into the Trendelenburg position with the head down 15 to 20 degrees, and a uterine manipulator was inserted.

2) Technique for SAWL

SAWL was performed using the following technique and using the simple instruments from Mizuho Medical Co., Ltd (Tokyo, Japan) shown in Fig. 3.

(1) A small incision is made into the umbilical fold with the tip of the scalpel so that the 5 mm trocar can be easily inserted.

(2) The surgeon and assistant then stand on the left and right sides of the patient and lift the abdominal wall. A 1.2 mm diameter Kirschner steel wire is inserted on the sagittal line, in the midline of the abdominal wall, from the upper part of the pubis toward the navel. The steel wire is threaded through a Nelaton catheter (Fig. 4-A) and fixed to a lifting handle to prevent skin damage (Fig. 4-B). The pierced Kirschner steel wire is cut with pliers about 2 cm past the insertion points, and the ends are bent upward.

(3) The abdominal wall is raised with the lifting handle, and the chain of the lifting handle is fixed to the lifting arm (Fig. 4-C).

2) How to create an abdominal port

To create an abdominal port, a small incision of 1.5 cm is made on either side of the abdominal wall, and the fascia was lifted using Kocher forceps and cut with scissors.

The muscle layer is bluntly dissected with long Pean forceps. The surgical field is developed using muscle hooks, and the fascia on the ventral side is penetrated to access the peritoneum. The peritoneum is grasped with a long pair of forceps and guided to the vicinity of the abdominal wall incision. Pean forceps are used to clamp the peritoneum in two locations (Fig. 4-D). A small incision is made with a scalpel to reach the abdominal cavity after confirming that the intestinal tract is not in proximity. The fascia and peritoneum are under tension because the abdominal wall is raised, and it is possible to easily reach the peritoneum by using long Pean forceps.

The peritoneum is clamped in four places with the Pean forceps (Fig. 4-E), and the Lap Protector® is inserted (Fig. 4-F). A 5 mm laparoscope is temporarily placed in the Lap Protector®, which monitors the

placement of a 5 mm trocar. This becomes the entrance for the laparoscope that will be used throughout the surgery (Fig. 4-G). This completes the establishment of the operation field required for the lifting technique.

3) Surgical procedure

In GRP-LS, the surgery is performed by inserting multiple forceps into the surgical port where the Lap Protector® is installed (Fig. 4-H, I). However, since the laparoscope uses a dedicated port installed in the navel, the procedure and use of forceps feels similar to conventional open surgery and allows easier navigation of surgical instruments than a single-incision LS (SILS)⁸ in which the laparoscope and multiple forceps are operated with one port.

3. Procedures for G3P-LS and G2P-LS

G3P-LS has been used since the introduction of the AWL method^{5,6}. This technique uses an abdominal port, which is first created in the umbilicus by an open surgery method, for a 10 mm laparoscope. After lifting the abdominal wall, the left and right lower abdominal walls are pierced by two 12 mm trocars while being monitored by a laparoscope; the inner cylinder is removed, and only the outer sheath remains. The trocar is punctured to create an abdominal port only when the lifting method is introduced, after which the method of creating ports is changed to the open method and the use of the sheath is discontinued, and it is changed to a Lap Protector®.

G2P-LS is a prototype of GRP-LS, with the surgery being performed using a single port created on one side of the abdominal wall. However, G2P-LS differs from GRP-LS in how the initial port is created and by the use of a 10 mm rather than a 5 mm laparoscope.

4. GSP-LS procedures

GSP-LS creates an abdominal port similar to the method for GRP-LS but does not create an umbilical laparoscopic port. Surgery is performed by simultaneously inserting the laparoscope and forceps into one abdominal port.

5. Items to be considered in this study

For each patient undergoing G3P-LS or GRP-LS, we looked at characteristics including age, body mass index (BMI), history of previous laparotomy, other operative procedures, number of surgeries performed by each surgeon, blood transfusion rate, transition to open surgery, postoperative complications, and number of surgeons during the procedure. We compared the number of surgeons and surgeries, classified by the number of surgeries experienced as a surgeon, in GRP-LS and G3P-LS, and the average number of surgeries per surgeon in each group.

The majority of our surgeries were laparoscopic ovarian cystectomies (LC) or laparoscopic myomectomies (LM), and we looked at whether the surgery was performed with GRP-LS or G3P-LS and

compared the length of the surgery and the blood loss. In the LC surgeries, we also compared unilateral and bilateral cystectomy surgeries for dermoid cysts and chocolate cysts.

6. Statistical analysis

The comparison between the two groups was evaluated using the Student t-test. The comparison between the three groups was evaluated using the Tukey's honestly significant difference (HSD) test, and the correlation between the groups was evaluated using the chi-square test. Statistical significance occurred at $p < 0.05$. Statistical analysis was performed using the Statistical Package for the Social Sciences version 26 (SPSS 26).

Results

1. Number of surgeries, surgical procedures, and surgical methods

We examined 5,419 cases of GLS performed using the AWL method: LC, 2,141 (39.5%); LM, 1,529 (28.2%); laparoscopic tubectomy (LT), 456 (8.4%); laparoscopic adnexectomy (LA), 384 (7.1%); laparoscopic assisted vaginal hysterectomy (LAVH), 202 (3.7%); total laparoscopic hysterectomy (TLH), 195 (3.6%); and other surgeries, 512 (9.4%).

GRP-LS was performed in 2,338 cases, and other gasless surgeries were performed in 3,081 cases: G3P-LS, 2,473; G2P-LS, 270; and GSP-LS, 338 (Table 1).

The patients undergoing either of the two operative procedures were similar in mean age, BMI and history of previous open surgeries. However, for obese patients over BMI 25, GRP-LS was 188 cases (8.0%) and G3P-LS was 256 cases (10.4%), which was significantly higher in G3P-LS ($p = 0.006$). There were only a few cases of severe obesity over BMI 35 in both groups (Table 2).

2. Percentage of each surgical procedure

The GRP-LS surgeries were 43.1% of the total; G3P-LS, 45.6%; GSP-LS, 6.2%; G2P-LS, 5% (Table 1). Until GSP-LS was introduced in 2004, all SAWLs were performed by G3P-LS.

GSP-LS, introduced in 2004, accounted for 42.9% of the total surgeries in 2006, but the percentage decreased after GRP-LS was introduced in 2005; GRP-LS was used in 84.3% of all surgeries by 2008. Although some procedures still require three or more ports (TLH, laparoscopic sacrocolpopexy [LSC], and laparoscopic pelvic lymphadenectomy [LPLA]), the percentage of GRP-LS in total SAWLs has exceeded 90% or more since 2011 (Fig. 5).

LM and LC are the most frequently performed surgeries, and Fig. 6 shows how the preferred surgical method has changed annually. For LM, most surgeries have been performed by GRP-LS since 2008. LC surgeries for unilateral ovarian tumors were increasingly performed by GSP-LS after 2004, but GRP-LS

quickly became the predominant method by 2007 (Fig. 6). Bilateral ovarian tumors and chocolate cysts were initially performed with G3P-LS, but most operations are now performed with GRP-LS.

3. Surgeons (Table 3).

Seventy-eight surgeons completed the GRP-LS procedures: 50% of surgeons had performed fewer than 20 surgeries, and 85.9% had carried out fewer than 50 surgeries; the latter group performed about half of the surgeries. G3P-LS was performed by 93 surgeons: 73.1% had performed fewer than 20 surgeries, and 89.2% had performed fewer than 50 surgeries; the latter group performed 39.0% of all surgeries. The percentage of surgeons who were novices, with fewer than 10 surgeries, was 37.2% for GRP-LS and 57.0% for G3P-LS. There was a bias in the proportion of surgeons for each number of experienced cases between the two surgical procedures ($p = 0.046$).

There was a significant bias between GRP-LS and G3P-LS when comparing the number of surgeries in each group divided by the number of surgeries experienced as a surgeon ($p < 0.001$). For GRP-LS, 1,163 surgeries (49.7%) were performed by surgeons who had carried out fewer than 50 surgeries. For G3P-LS, a smaller percentage of surgeons had performed fewer than 50 surgeries: 963, 38.9%.

The average number of surgeries per surgeon increased as the number of surgeries experienced increased, but there was no bias between the surgeons in both operative procedures.

4. Results of surgical procedures

The patients who underwent GRP-LS for LM were significantly older ($p = 0.002$), had a shorter time in surgery ($p = 0.006$), and reduced blood loss ($p < 0.001$) than G3P-LS (Table 4). Compared to G3P-LS, the patients with LCs who underwent GRP-LS for dermoid cysts had a significantly reduced time spent in surgery ($p < 0.001$) and reduced blood loss ($p < 0.001$) for unilateral tumors and significantly reduced blood loss ($p = 0.044$), with the same time spent in surgery for bilateral tumors ($p = 0.309$).

When compared to G3P-LS, patients undergoing surgery for chocolate cysts using GRP-LS were significantly older in unilateral ($p = 0.004$) and bilateral tumors ($p = 0.002$) and had a significantly higher BMI for bilateral tumors ($p < 0.001$). GRP-LS significantly reduced the time spent in surgery for unilateral tumors ($p < 0.001$), compared to G3P-LS, but with similar blood loss ($p = 0.092$). For bilateral cysts, GRP-LS showed no significant difference in time spent in surgery and blood loss compared to G3P-LS (Table 5).

Patients undergoing GRP-LS for LT were significantly older ($p = 0.037$) and had shorter operative time ($p < 0.001$) compared to G3P-LS (Table 6).

5. Complications (Table 7)

GRP-LS was significantly associated with the reduction of intraoperative ($p = 0.006$) and postoperative complications ($p < 0.001$), compared to G3P-LS. Subcutaneous bleeding was the most common postoperative complication with G3P-LS, but almost disappeared with GRP-LS. But no significant bias was observed between the two groups in the blood transfusion rate ($p = 0.312$). Only two of the 2,338 (0.09%) surgeries performed with GRP-LS had to transition to open surgery in mid-operation due to intestinal injury and severe adhesion. But 13 of 2,473 surgeries performed with G3P-LS (0.53%) had to transition to open surgery. The detailed reasons for these are that seven patients (0.53%) had severe adhesions and heavy bleeding, three had intraoperative complications (0.23%), and three patients had malignant ovarian tumors (0.23%).

Discussion

Strictly speaking, GRP-LS is a two-port laparoscopic surgery, but the first approach of the port is performed on the flank, with the abdominal wall lifted, using the open method. A 5 mm trocar is inserted into the umbilical fold using laparoscopic monitoring to create a laparoscopic port. For this reason, the puncture wound in the umbilical fossa is hardly noticeable in the early postoperative period. In the open method, it is difficult to place a 5 mm trocar on the umbilicus because the first approach must be performed with a small incision. One advantage of the lateral approach with GRP-LS is that the laparoscopic port of the umbilicus can be installed safely and easily.

The great advantage of GRP-LS is that it does not require the same advanced technical skills required for conventional LS. The surgical procedure of GRP-LS, performed by inserting multiple forceps into one port, is similar to SILS. However, a major difference between the two procedures is that the surgical field is approached with the forceps and endoscope from different directions; thus, the forceps can be better manipulated during GRP-LS compared to SILS. In addition, GRP-LS allows instruments such as forceps, needle holders, scissors, and electric scalpels, traditionally used in conventional open surgery, to be used in LS.

Even a novice can sufficiently operate the forceps if the surgeon has acquired the basic forceps techniques learned in open surgery; it is not necessary to learn the surgical technique of the pistol-type forceps used in conventional LS. The movement of the forceps is restricted when using a trocar; using the Lap Protector, however, allows surgical procedures to be carried out that would normally require multiple ports and a 15 mm incision (the same size as the wound of a 12 mm port).

The Lap Protector allows expansion of the abdominal wall port and provides sufficient space for performing multiple-forceps operations, manipulating a needle, and extracting excised material. The Lap Protector also protects the wound and helps stop bleeding. It is considered that the fact that the postoperative complication of subcutaneous bleeding in GRP-LS has almost disappeared as compared with G3P-LS is due to the use of Lap Protector and the reduction of the number of treatment ports to one.

Generally, a decrease in the number of ports is considered a disadvantage in surgical procedures; however, in GRP-LS, the endoscope and the forceps are situated in different directions than are used in

SILS. During GRP-LS, a Lap Protector is used rather than a trocar, and the port can be used more effectively even though the abdominal wall incision is the same size; therefore, it is possible to use several forceps inserted into one port. Furthermore, since GRP-LS can be operated using forceps and needle holders that are familiar in laparotomy, difficult operations such as suture ligation and traction in LM can be easily performed.

G3P-LS, which is performed in cooperation with an assistant, helps to train an inexperienced surgeon, but once the surgeon becomes accustomed to the GRP-LS technique, which allows the use of multiple forceps in one port, the surgeon will not need an assistant. The superior ease of the GRP-LS technique compared to G3P-LS is why GRP-LS became the predominant method within three years of its introduction.

When the surgical results of GRP-LS for fibroids were compared with those of G3P-LS, it was observed that the weight and number of fibroids removed were the same with both techniques, but favorable results, such as a shortened operative time and reduced blood loss, were observed with GRP-LS.

An extracorporeal method was used for LC and LT procedures, in addition to intraperitoneal manipulation. In the extracorporeal method, the trocar is removed, and the ovaries and fallopian tubes are guided near the abdominal wall or outside the body to perform surgery with the naked eye without using an endoscope. With GLS, it is possible to perform extracorporeal surgery safely by adjusting the elevation of the abdominal wall. In terms of LC and LT results, GRP-LS showed a significant reduction in operative time and blood loss compared to G3P-LS, and no non-inferiority of GRP-LS was observed. Thus, it was clarified that GRP-LS is not only superior in abdominal wound but also in surgical results compared to G3P-LS.

GRP-LS had fewer instances (0.09%) where a transition to open surgery was required compared to G3P-LS (0.53%); this rate of transition to open surgery are very low compared to that of the pneumoperitoneum method (0.27%: 424/157,586 cases) ¹⁰.

The establishment of the GRP-LS technique reduced the need for a transition to open surgery due to technical difficulties; in addition, there are fewer complications because of the advantages GRP-LS provides for the manipulation of forceps; a simultaneous increase in the use of MRI increased the likelihood that malignant tumors could be discovered before surgery.

In this study, GRP-LS was performed by 78 surgeons and G3P-LS was performed by 93 surgeons, respectively. In GRP-LS, novice surgeons with fewer than 50 surgical experiences accounted for 85.9% of the total amount of surgeons in this category, which performed approximately half of the surgeries. In G3P-LS, surgeons with fewer than 50 surgical experiences accounted for 89.2% of the total amount of surgeons in this category, while the number of surgeons with less than 10 surgical experiences amounted to 57% of the total number of surgeons. It is speculated that these surgeons completed the surgery with the strong assistance of a skilled assistant. On the other hand, in GRP-LS, since it is a solo surgery in which a surgical procedure is performed without an assistant, it truly shows the ability of the surgeon

himself. From this, it is shown that GRP-LS is a surgical method that is easy to learn for beginners in laparoscopic surgery.

Despite the fact that there is no bias in the average number of surgeries per surgeon among the groups of surgeons classified by the number of surgical experiences as a surgeon, the proportion of surgeries by surgeons with fewer than 20 surgical experiences decreased from 18.4–9.7% when GRP-LS and G3P-LS were compared, and conversely increased from 39.0–49.7% for surgeons with less than 50 surgical experiences. This means that the number of novice surgeons who continue to operate on GRP-LS has increased, and it is a factor in the facilitation to the introduction of GRP-LS. Moreover, the overall results including the low rate of complication rates and no transition to open surgery in GRP-LS this time are showing that it can easily be achieved by senior surgeons as well as many beginners.

In obese patients, surgeons performing GLS find it difficult to establish a good operative field ⁶. Generally, in severely obese cases, the abdominal wall is thick, so even if the abdominal wall is lifted, the fat in the abdominal wall hangs down and a good operative field is often not obtained. However, in this study, the effect was hardly observed. This is thought to be due to the fact that the average BMI of Japanese women is 22.6 ¹¹ (In this study, 0.1% of cases had a BMI of 35 or higher), which is very low compared to Westerners ^{12, 13}.

In patients with a BMI of less than 35, we overcame this challenge by placing the patient at an angle and raising the pelvic height (a 30-degree Trendelenburg position). In patients with a BMI above 35 degrees, we combine GLS and pneumoperitoneum using EZ Access® (Hakko Co., Ltd.) ¹⁴. In this case, the intra-abdominal pressure of the pneumoperitoneum can be suppressed by being combined with GLS, and we would like to further examine the usefulness of this hybrid method for severely obese patients by looking at variables such as pneumoperitoneum pressure, Trendelenburg position angle, and the number and position of ports.

Conclusions

Over 5,000 surgeries have been performed with GLS, and the technique of GRP-LS continues to improve. Our study demonstrates that it is an effective surgery that is easy to learn and has few complications. This GLS requires less complex preparation than conventional GLS and leaves the patients with less cosmetic damage. Few procedures require a transition to conventional surgery, so it is appropriate for inexperienced laparoscopic surgeons.

Abbreviations

GRP-LS: gasless reduced-port laparoscopic surgery; G3P-LS: gasless 3-port laparoscopic surgery; LM: laparoscopic myomectomy; LC: laparoscopic myomectomy; LT: laparoscopic salpingectomy; LA: laparoscopic adenectomy; LS: laparoscopic surgery; AWL: abdominal wall lifting method; SAWL: subcutaneous abdominal wall lifting method; CO₂: carbon dioxide; GLS: gasless laparoscopic surgery;

G2P-LS: gasless 2-port laparoscopic surgery; GSP-LS: gasless single-port laparoscopic surgery; SILS: single-incision laparoscopic surgery; BMI: body mass index; LAVH: laparoscopic assisted vaginal hysterectomy; TLH: total laparoscopic hysterectomy; LSC: laparoscopic sacrocolpopexy; LPLA: laparoscopic pelvic lymphadenectomy.

Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Review Board of Tokyo Medical University (approval number: T2020-0089), and conducted in accordance with the principles of the Declaration of Helsinki.

All patients were given the written informed consent to the surgical procedure and to the use of individual data for research.

Consent for publication

All patients were given the written informed consent to the surgical procedure and to the use of individual data for research.

Availability of data and materials

The datasets used and analyzed during the current study available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

No funding was provided for this study.

Authors' contributions

HI, JK and SY were responsible for data collection. HI, TA and KI drafted initial versions of the manuscript. KI provided the statistical analyses. HI and KI were involved in data interpretation and manuscript development. All authors approved of the final manuscript version.

Acknowledgements

Not applicable.

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Tables

Table 1: Number of cases of surgical procedures for each gasless laparoscopic surgery.

Table 1

gasless lapaeoscopic surgeries		operative procedures								rate of total number (%)
		LC	LM	LT	LA	LAVH	TLH	others	Total	
GRP-LS	No. of cases	804	980	240	180	0	0	134	2338	43.1
	%	34.4	41.9	10.3	7.7	0.0	0.0	5.7	100.0	
G3P-LS	No. of cases	1019	379	166	158	202	195	354	2473	45.6
	%	41.2	15.3	6.7	6.4	8.2	7.9	14.3	100.0	
GSP-LS	No. of cases	218	41	29	34	0	0	16	338	6.2
	%	64.5	12.1	8.6	10.1	0.0	0.0	4.7	100.0	
G2P-LS	No. of cases	100	129	21	12	0	0	8	270	5.0
	%	37.0	47.8	7.8	4.4	0.0	0.0	3.0	100.0	
Total No. of cases		2141	1529	456	384	202	195	512	5419	100
%		39.5	28.2	8.4	7.1	3.7	3.6	9.4	100	

Table 2: Comparison of patient backgrounds in GRP-LS and G3P-LS

Table 2

Patient background	GRP-LS (n = 2338)	G3P-LS (n = 2473)	p-value
age, years (mean±SD)	36.6 ± 8.6	35.9 ± 10.1	0.607
BMI, kg/m ² (mean±SD)	20.9 ± 2.8	21.1 ± 6.2	0.056
< 18.5, n (%)	367 (15.7)	391 (15.8)	0.914
18.5 ≤ < 25, n (%)	1783 (76.3)	1826 (73.8)	0.052
25 ≤ < 30, n (%)	162 (6.9)	188 (7.6)	
30 ≤ < 35, n (%)	23 (1.0)	65 (2.6)	0.006
35 ≤, n (%)	3 (0.1)	3 (0.1)	
No. of cases with previous surgery, n (%)	324 (13.9)	386 (15.6)	0.087
Open surgery, n (%)	117 (5.0)	113 (4.6)	0.480
Cesarean section, n (%)	49 (2.1)	31 (1.3)	0.022
Laparotomy, n (%)	64 (2.7)	75 (3.0)	0.541
Multiple surgeries, n (%)	4 (0.2)	7 (0.3)	0.416
Laparoscopic surgery, n (%)	75 (3.2)	60 (2.4)	0.101
Appendectomy n (%)	122 (5.2)	202 (8.2)	<0.001
Inguinal hernia, n (%)	10 (0.4)	11 (0.4)	0.928

Table 3: Comparison of the number of surgeons and surgeries in GRP-LS and G3P-LS**Table 3**

	Surgical procedure	Total number	No. of surgeries experienced as a surgeon						p-value
			1-10	11-20	21-30	31-50	51-100	100<	
No. of surgeons (%)	GRP-LS	78 (100)	29 (37.2)	10 (12.8)	13 (16.7)	15 (19.2)	9 (11.5)	2 (2.6)	0.046
	G3P-LS	93 (100)	53 (57.0)	15 (16.1)	8 (8.6)	7 (7.5)	7 (7.5)	3 (3.2)	
No. of surgeries (%)	GRP-LS	2338 (100)	80 (3.4)	147 (6.3)	348 (14.9)	588 (25.1)	608 (26.0)	567 (24.3)	< 0.001
	G3P-LS	2473 (100)	222 (9.0)	233 (9.4)	202 (8.2)	306 (12.4)	537 (21.7)	973 (39.3)	
Average No. of surgeries per surgeon	GRP-LS		2.8	14.7	26.8	39.2	67.6	283.5	0.987
	G3P-LS		4.2	15.5	25.3	43.7	76.7	324.3	

The number of surgeons and surgeries, classified by the number of surgeries experienced as a surgeon and the average number of surgeries per surgeon in each group.

Table 4: Comparison of patient background and surgical results in LM using GRP-LS and G3P-LS**Table 4**

Characteristics	GRP-LS (n = 980)	G3P-LS (n =379)	p-value
age, years (mean±SD)	37.3 ± 5.0	36.1 ± 4.9	0.002
BMI, kg/m ² (mean±SD)	21.1 ± 2.7	20.7 ± 3.6	0.851
operative time, min. (mean±SD)	155 ± 56	160 ± 53	0.006
blood loss, ml (mean±SD)	155 ± 212	247 ± 370	< 0.001
weight of fibroids removed, (mean±SD)	173 ± 122	171 ± 139	0.075
No. of fibroids removed, (mean±SD)	5.0 ± 4.7	4.1 ± 4.5	0.152

Table 5: Comparison of patient background and surgical results in LC using GRP-LS and G3P-LS

Table 5**Dermoid cyst**

Characteristics	Operative procedure	GRP-LS	G3P-LS	p-value
		No. of U = 190 No. of B = 39	No. of U = 217 No. of B = 57	
age, years (mean±SD)	U	31.2 ± 6.9	29.9 ± 6.3	0.082
	B	28.7 ± 5.2	29.8 ± 5.8	0.352
BMI, kg/m ² (mean±SD)	U	20.5 ± 2.8	20.7 ± 3.0	0.508
	B	20.7 ± 3.4	20.9 ± 3.3	0.745
operative time, min. (mean±SD)	U	84 ± 69	119 ± 46	< 0.001
	B	128 ± 38	135 ± 36	0.309
blood loss, ml (mean±SD)	U	21 ± 39	52 ± 76	< 0.001
	B	52 ± 83	101 ± 123	0.044

Chocolate cyst

Characteristics	Operative procedure	GRP-LS	G3P-LS	p-value
		No. of U = 162 No. of B = 87	No. of U = 263 No. of B = 157	
age, years (mean±SD)	U	32.7 ± 5.7	31.1 ± 5.6	0.004
	B	34.1 ± 5.7	31.6 ± 5.9	0.002
BMI, kg/m ² (mean±SD)	U	20.0 ± 2.8	20.4 ± 2.5	0.141
	B	21.3 ± 2.6	19.7 ± 2.9	< 0.001
operative time, min. (mean±SD)	U	100 ± 35	128 ± 38	< 0.001
	B	135 ± 39	142 ± 39	0.219
blood loss, ml (mean±SD)	U	77 ± 121	104 ± 173	0.092
	B	185 ± 224	150 ± 183	0.203

U means unilateral LC and B means bilateral LC.

Table 6: Comparison of patient background and surgical results in LT using GRP-LS and G3P-LS**Table 6**

Characteristics	GRP-LS (n = 240)	G3P-LS (n = 166)	p-value
age, years (mean±SD)	32.0 ± 5.2	30.8 ± 5.9	0.037
BMI, kg/m ² (mean±SD)	20.4 ± 2.2	20.4 ± 2.6	0.788
operative time, min (mean±SD)	70 ± 31	110 ± 40	< 0.001
blood loss, ml (mean±SD)	165 ± 444	231 ± 405	0.140

Table 7: Comparison of complications in GRP-LS and G3P-LS

Table 7

Complications	GRP-LS (n = 2338)	G3P-LS (n = 2473)	p-value
Intraoperative complication, n (%)	2 (0.09)	13 (0.53)	0.006
bladder injury, n	0	4	
subcutaneous emphysema, n	0	3	
intestinal injury, n	1	2	
lost needle, n	1	1	
others, n	0	3	
Postoperative complication, n (%)	6 (0.26)	51 (2.06)	< 0.001
subcutaneous bleeding, n	3	36	
intraperitoneal bleeding, n	2	4	
pelvic peritonitis, n	1	3	
wound infection, n	0	3	
others, n	0	5	
Blood transfusion, n (%)	23 (0.98)	32 (1.29)	0.312
Transition to open surgery, n (%)	2 (0.09)	13 (0.53)	< 0.001

Figures

Fig. 1

A

B

C

Figure 1

Gasless 3-port laparoscopic surgery (G3P-LS) and Gasless reduced-port laparoscopic surgery (GRP-LS) A: Early type of gasless 3-port laparoscopic surgery (G3P-LS): the abdominal wall is lifted using two thick steel wires and two lifting bars. B: Modified G3P-LS: the abdominal wall is lifted using a thin steel wire and a lifting bar. The surgeon and assistant simultaneously perform the surgery using the left and right ports. C: Gasless reduced-port laparoscopic surgery (GRP-LS): The surgeon inserts multiple forceps into one port to perform surgery.

Fig. 2

Figure 2

Types of gasless laparoscopic surgery The illustration shows the difference in types and positions of ports created on the abdomen in G3P-LS, Gasless 2-port laparoscopic surgery (G2P-LS), Gasless single-port laparoscopic surgery (GSP-LS), and GRP-LS surgeries.

Fig. 3

Figure 3

The lifting instruments required for the abdominal wall lifting method (SAWL): a lifting bar, a lifting handle, a 1.2 mm Kirshner stainless-steel needle, a Nelaton catheter, and pliers.

Fig. 4

Figure 4

Procedures for the abdominal wall lifting method (SAWL) A: The Kirschner wire is inserted subcutaneously along the sagittal line of the median abdominal wall from the suprapubic region toward the umbilicus and threaded through a protective Nelaton catheter. B: The Kirschner wire protected with the Nelaton catheter is fixed to the lifting handle. C: The chain of the lifting handle is fixed to the lifting arm. D: Pean forceps are used to clamp the peritoneum in two locations. E: The freed peritoneum is held with Pean forceps at four sites. F: A Lap Protector® is inserted into the abdominal wall aperture. G: A 5 mm trocar is inserted via the umbilical fossa under the surveillance of the endoscope. H: An electric scalpel and a suction tube are inserted into the Lap Protector to make an incision on the surface of the uterine fibroid (upper right image). I: Outside view of the GRP-LS.

Fig. 5

Figure 5

Yearly trends of the different forms of gasless laparoscopic surgery. The use of GRP-LS increased every year after 2005; by 2008, it accounted for almost 90% of laparoscopic surgeries including total laparoscopic hysterectomy (TLH) and laparoscopic sacrocolpopexy (LSC) requiring 3 ports. The use of conventional G3P-LS decreased every year after 2005, to a current usage rate of approximately 10%.

Fig. 6

Figure 6

Yearly trends in the percentage of GRP-LS for each surgical procedure. White circle: the annual rate of laparoscopic myomectomy (LM) using GRP-LS. Black circle: the annual rate of laparoscopic ovarian cystectomy (LC) using GRP-LS. White triangle: the annual rate of laparoscopic tubectomy (LT) using GRP-LS.