Surgical training in extraperitoneal laparoscopic para-aortic lymphadenectomy for the treatment of gynecological cancer using a Thiel-embalmed cadaver

SHOJI NAGAO[1], MASAAKI ANDOU[2], KYOHEI IRIE[1,3], KOTARO KUBO[1], NAOYUKI IDA[1], TAKAAKI KOMIYAMA[3], TOSHIYA KAMEOKA[3], AYANO KAWAGUCHI[3] and HISASHI MASUYAMA[1]

[1]Department of Obstetrics and Gynecology, Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences, Okayama University, Okayama 700-8558; [2]Department of Obstetrics and Gynecology, Kurashiki Medical Center, Kurashiki, Okayama 710-8522; [3]Department of Human Morphology, Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences, Okayama University, Okayama 700-8558, Japan

Received March 17, 2024; Accepted April 10, 2024

DOI: 10.3892/ol.2024.14422

Abstract. The extraperitoneal laparoscopic approach (ELPAN) for para-aortic lymphadenectomy provides excellent visibility of the left side of the aorta, thus facilitating surgery in the retroperitoneal space. This technique is highly complex compared with the transperitoneal approach. In particular, advanced techniques are required to develop an appropriate surgical field in the narrow retroperitoneal space; therefore, surgeons need to undergo a significant amount of training to become competent. A variety of tools are available for surgical training but are limited by their ability to reproduce complex anatomy. Thus, cadavers may represent the most suitable tool for learning this unique technique. The present study describes a surgical training protocol for the ELPAN technique using a Thiel-embalmed human cadaver and provides a step-by-step description of the ELPAN technique performed at Okayama University (Okayama, Japan). A 72-year-old Thiel-embalmed female cadaver was used to develop a protocol for surgical training in the ELPAN technique that effectively reproduced the methodology required in clinical practice. A training method for ELPAN surgery was developed and successfully completed using the Thiel-embalmed cadaver that secured the surgical field in the retroperitoneal space and permitted resection of the lymph nodes. The Thiel-embalmed cadaver tissue possessed excellent properties for surgical training, including color tone, flexibility, and the membrane structure of connective and fat tissues. In addition, this method of fixation preserved stiffness and elasticity of the peritoneum, although large vessels were slightly fragile and poorly extensible. Surgical training using a Thiel-embalmed human cadaver represents a valuable option for learning the ELPAN surgical technique. However, this technique may be unsuitable for training in perivenous manipulation. To the best of our knowledge, this is the first report to describe the use of Thiel-embalmed cadavers as a tool for surgeons to undergo training in the ELPAN technique.

Correspondence to: Professor Shoji Nagao, Department of Obstetrics and Gynecology, Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences, Okayama University, 2-5-1 Shikata-cho, Kita-ku, Okayama 700-8558, Japan
E-mail: s_nagao@okayama-u.ac.jp

Key words: human, endometrial cancer, laparoscopic surgery, extraperitoneal laparoscopic para-aortic lymphadenectomy, surgical training, cadaver

Introduction

Para-aortic lymphadenectomy has become the standard method for staging or treating gynecological malignancies (1). The laparoscopic modification of para-aortic lymphadenectomy was first reported in 1995 and is primarily utilized to evaluate para-aortic metastasis in patients with cervical cancer who are scheduled to receive radiation therapy (2,3). More recently, this method has become a common technique with which to stage endometrial cancer (4,5). In Japan, this technique has been covered by public insurance for patients with endometrial cancer since April 2020. However, there is an ongoing debate relating to whether the extraperitoneal or transperitoneal route should be adopted to approach the para-aortic lymph nodes when performing lymphadenectomy.

Previous meta-analyses compared para-aortic lymphadenectomy using the extraperitoneal laparoscopic approach (ELPAN) with transperitoneal laparoscopic approaches in patients with endometrial cancer and reported that the ELPAN led to the successful harvesting of a higher number of para-aortic lymph nodes (6,7). In addition, the left-sided extraperitoneal technique was found to facilitate easy access to the left aortic nodes, which comprise 63% of all aortic nodes (8,9). However, prostration of the inferior vena cava due to the presence of a pneumoperitoneum has been found to complicate a surgeon's ability to gain access to the right aortic nodes when applying the left-sided extraperitoneal technique. To approach the lymph nodes in front of the inferior vena cava, it is necessary to cross over the inferior aorta. Therefore, there is an urgent need to develop a new technique to help secure the visual field for surgery in the retroperitoneal space. The ELPAN has been associated with a longer learning curve; a previous study reported that surgical competence in this technique can be achieved after approximately 60 procedures (10). Therefore, it is vital to develop dedicated training tools that would permit surgeons to learn the ELPAN technique in a safe environment. Recent reports have suggested that the use of cadavers may represent a valuable tool for surgical training (11).

In 1992, Walter Thiel described an embalming method based on a mixture of ammonium nitrate, boric acid, and ethylene glycol, which maintained human post-mortem tissues in a 'life-like' state (12). The subsequent introduction of soft-fixed cadavers using the Thiel embalming method has substantially improved the flexibility and color retention of cadavers used for surgical training (13). As regards the retroperitoneal surgical approach, it is vital that a surgeon develops the ability to secure a visual field by extending the peritoneum but without causing damage. When fixed by Thiel's method, cadavers retain both tissue flexibility and plasticity and may represent a suitable tool for surgeons to learn the retroperitoneal approach with a pneumoperitoneum. However, to the best of our knowledge, there is no surgical training option available for surgeons to learn the ELPAN technique using Thiel-embalmed cadavers. Herein, we report the development and implementation of a surgical training method for the ELPAN technique using a Thiel-embalming cadaver.

Materials and methods

Training overview and participants. We developed a training protocol for surgeons to learn the ELPAN technique on two female cadavers that had been fixed using the Thiel embalming method. Four gynecological oncologists, from three institutions, participated in this training exercise. Three of the gynecological oncologists had gained >10 years of experience in laparoscopic surgery. Two of the gynecological oncologists had previously performed the ELPAN technique in a few cases and had just introduced the procedure into clinical practice; the other two gynecological oncologists had no previous history of performing the ELPAN technique. The four participants were divided into groups of two and then received training in the ELPAN technique. The instructor was an expert in laparoscopic surgery with extensive experience in the ELPAN. Seven visitors were asked to act as witnesses for the training program. The ELPAN training program was completed on a single day; subsequently, the cadavers were offered to junior doctors to perform training exercises in laparoscopic hysterectomy.

Preparations for cadavers. The Thiel-embalmed cadavers were prepared for the training exercise in a specific manner. First, two cannulas were inserted into the femoral artery; one in the direction of the head and one in the direction of the foot. Next, we prepared a pretreatment solution by calculating the volume of 20% propylene glycol required for the virtual weight of the cadaver by considering a body mass index (BMI) of 18 kg/m^2 and the cadaver's height. Then, we mixed 6% formalin, 12.5% ethanol, and Thiel fixative solution (Liquid d; Nisshin EM Co., Ltd., Tokyo, Japan) to prepare a volume of fixative that was 1.5-fold larger than the volume of the pretreatment solution. Perfusion fixation was then performed using a tubing pump (TP-20SA, AS ONE Corporation, Osaka, Japan) at a flow rate of 500 ml/min. An ENSEAL™ Curved Tissue Sealer (ETHICON, Raritan, NJ, USA) was used for coagulation and dissection.

Results

Surgical procedure. We successfully developed a training protocol for surgeons to learn the ELPAN technique using a 72-year-old female cadaver (height: 153 cm; weight, 39 kg). This technique was taught to two groups of gynecological oncologists. The surgical procedure was performed in 13 key steps, as follows:

Step 1: An incision of approximately 1 cm in diameter was made in the navel region to access the abdominal cavity to permit the insertion of a camera port. Then, a normal pneumoperitoneum was created; this was possible because the cadaver had a similar level of flexibility in the abdominal wall as that of a living body. The color of the small intestine was very similar to that of a living body but appeared to have collapsed and felt harder than living tissue.

Step 2: A 30-mm incision was made approximately 3 cm medial to the left iliac spine. Then, we used an electrical scalpel to open the skin, subcutaneous fat, and fascia.

Step 3: The surgeon introduced his or her right index finger into the incision and created an extraperitoneal space. Then forceps were used to perform blunt dissection of the peritoneum extending from the left 12th rib to the inguinal ligament (Fig. 1). Although the peritoneum was harder than that of a living body, its flexibility and extensibility had been maintained sufficiently.

Step 4: After preparing the extraperitoneal space, a 10-mm Blunt Tip Trocar was introduced. Then a pneumoretroperitoneum was established using carbon dioxide gas at a pressure of 10 mmHg. The 10-mm Blunt Tip Hasson Trocar (KANGJI, Hangzhou, China) was then used to introduce the laparoscope. The pneumoretroperitoneum stretched the peritoneum in the same manner as in a living body, and a space was secured in the retroperitoneal cavity that was similar to that of a living body. The fat tissue of the retroperitoneum was slightly inflexible; however, the color tone was similar to that of a living body, and the surgeon's feeling during stripping was very similar to that experienced in a living body.

Step 5: Two additional trocars, including ports for a 5-mm E/Z trocar (Hakko Medical JP) and a 12 mm ENDOPATH XCEL trocar (ETHICON, Raritan, USA), were inserted along the anterior axillary line, separated by a distance of approximately 6 cm. After enlarging the caudal detachment of the lateral umbilical ligament, a fourth trocar (a 12-mm ENDOPATH XCEL trocar) was inserted into the groin. The laparoscope was then transferred to the fourth trocar.

Step 6: Next, forceps were used to perform blunt dissection on the anterior surface of the left psoas muscle and the common iliac artery. Then, the tissue was released medially from the left psoas muscle to identify the left ureter (Fig. 2). Further medial extension was performed, and the left common iliac artery and aorta were identified. Dissection was then

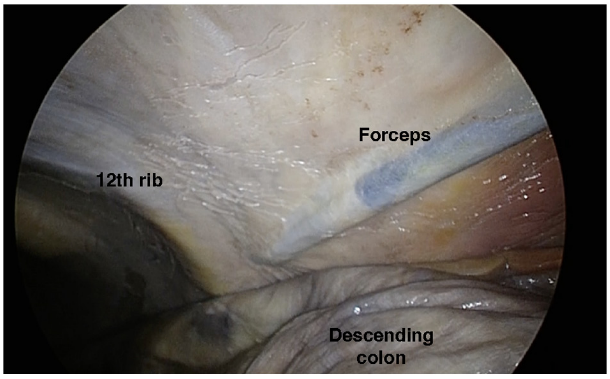

Figure 1. The extensibility and strength of the peritoneum in the cadaver are sufficient. These properties permitted the use of forceps for blunt dissection without any issues.

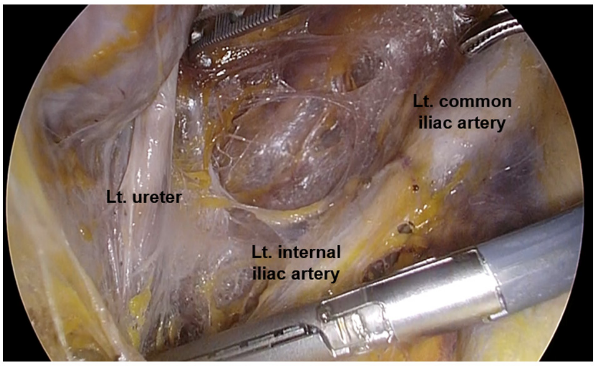

Figure 2. Identification and detachment of the Lt. ureter from the common iliac artery. The extensibility of the ureter, along with the color tone and flexibility of the connective tissue, are very similar to that in a living body. Lt., left.

continued cranially to a point that was a few centimeters above the inferior mesenteric artery. The flexibility of the tissue on the ceiling of the surgical field, along with the color and hardness of the ureters, were very similar to those of a living body. In contrast, the large vessels were slightly fragile and exhibited poor levels of extension.

Step 7: Next, the anterior separation of the left common iliac artery was expanded to the right to identify the right common iliac artery, vena cava, and right ureter (Fig. 3). Detachment of the right side of the vena cava was then extended cranially to identify the origin of the right ovarian vein. The inferior vena cava was stiffer than that of a living body and exhibited significant collapse; consequently, the tactile sensation was slightly different from that of normal surgery.

Step 8: Next, the cranial membranous tissue of the inferior mesenteric artery was punctured and the cranial space was opened to reveal the left renal vein (Fig. 4).

Step 9: Next, the left para-aortic and common iliac nodes were detached from the artery using sharp and blunt dissection (Fig. 5).

Step 10: The presacral nodes were resected (Fig. 6).

Step 11: The precaval lymph nodes were identified and detached from the inferior vena cava (Fig. 7).

Step 12: Tissue that had developed between the aorta and vena cava was stripped and excised.

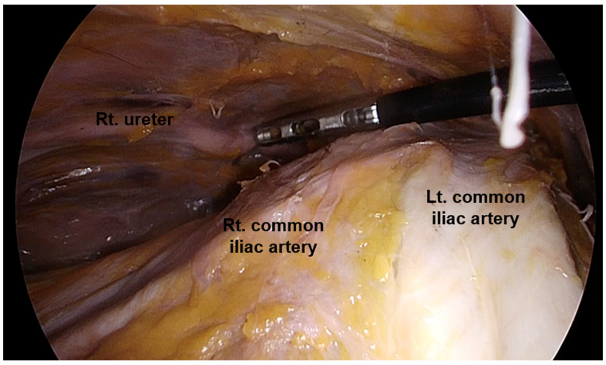

Figure 3. The Rt. ureter is identified, and the dissection is extended to the right. This strategy secured a sufficient field-of-view. Lt., left; Rt., right.

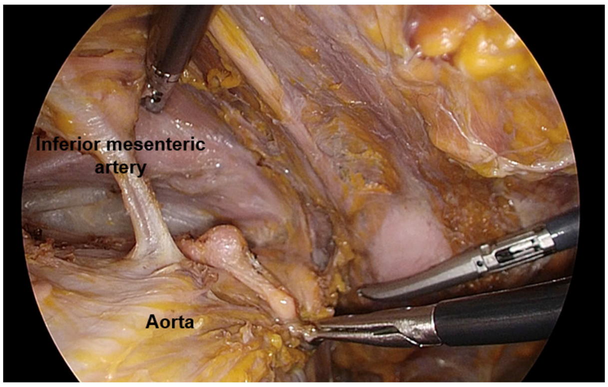

Figure 4. The retroperitoneal space is expanded to the cranial side of the inferior mesentery artery. The color tone and flexibility of the tissues around the inferior mesentery artery are similar to those in a living body.

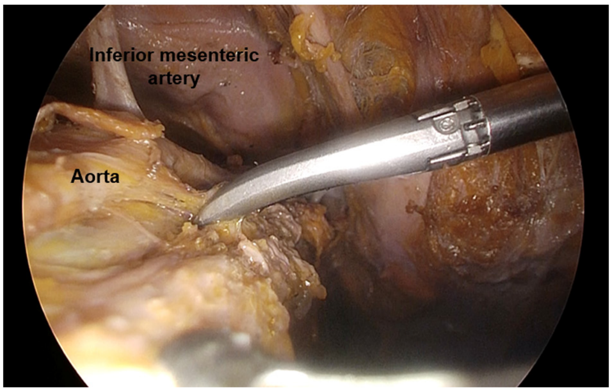

Figure 5. Resection of the lymphoid tissue on the left side of the aorta. The color tone and flexibility of the fat and lymphatic tissue are maintained in the cadaver, and the tactile sensation experienced by the surgeon is almost identical to that experienced with a living body. However, the arteries had collapsed and their elasticity differed from that of a living body.

Step 13: Finally, the surface of the vena cava was ligated as a training exercise that simulated the reparative procedure for blood vessel damage. As the strength of the vein wall was insufficient, it was assumed that the blood vessel wall would tear easily upon ligation.

Gynecologic oncologists with prior ELPAN experience completed steps 1-12 in 3 h 45 min, after which they practiced

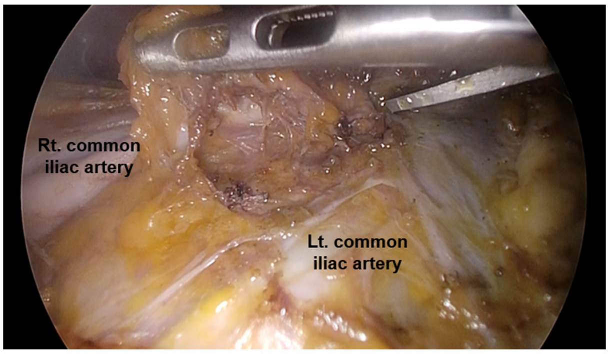

Figure 6. Resection of the presacral nodes. The color tone and flexibility of the fat and lymphatic tissue are maintained in the cadaver, and the tactile sensation experienced by the surgeon is very similar to that experienced with a living body. Lt., left; Rt., right.

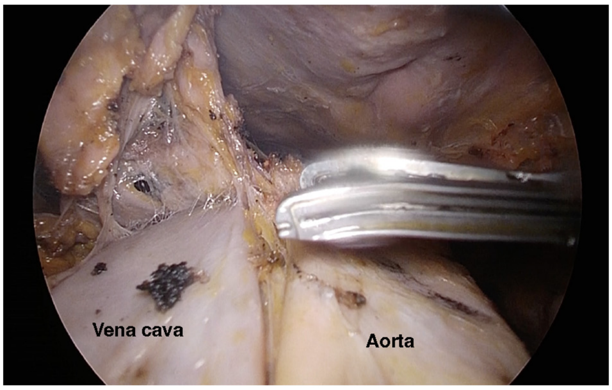

Figure 7. Detachment of the precaval lymph nodes from the inferior vena cava. The color tone and flexibility of the tissue are maintained in the cadaver, and the tactile sensation experienced by the surgeon is very similar to that experienced with a living body. However, the vena cava had collapsed and lost its elasticity.

suturing the vena cava in step 13. Gynecological oncologists with no experience in ELPAN implementation also completed steps 1-12, but took more than 5 h.

Effects of the surgical training. A post-training questionnaire survey showed that all participants were highly satisfied with this method of ELPAN surgical training. Furthermore, the gynecological oncologist participants introduced ELPAN for endometrial cancer into clinical practice, and have performed ELPAN on nearly 20 cases during the 6 months following training. We continue to regularly conduct cadaver surgical training to enhance ELPAN proficiency among surgeons.

Discussion

In the present study, we demonstrated that the stiffness and elasticity of the peritoneum were firmly maintained in a Thiel-embalmed human cadaver. As a result, it was possible to have a pneumoperitoneum similar to that of living tissue and secure an appropriate visual field in the retroperitoneal space for surgery. In addition, the color tone, flexibility, and membrane structure of the connective and adipose tissues were sufficiently maintained in the Thiel-embalmed human cadaver. Thus, the condition of the tissues in the Thiel-embalmed human cadaver was very similar to that of a living body; furthermore, the tactile sensations during training were comparable to that experienced during surgery in clinical practice. Therefore, surgical training protocols that utilize a Thiel-embalmed cadaver can be considered as highly valuable tools for learning the ELPAN technique. However, the large vessels were fragile and exhibited poor extension. Therefore, this technique may be unsuitable for surgical training involving vascular ligation suturing techniques.

Previous meta-analyses have reported that the ELPAN technique has certain advantages when compared with transperitoneal laparoscopic para-aortic lymphadenectomy (6,7). For example, the ELPAN technique makes it easier for the surgeon to approach the lymph nodes on the left side of the large vessels and can be easily applied in cases that involve intra-abdominal adhesions. However, some technical issues have been associated with ELPAN, including the need to secure a unique field of view that is unfamiliar to gynecologists. Consequently, there is an urgent need to develop novel techniques that allow surgeons to approach the space on the right side of the large vessels.

The safe and efficient introduction of ELPAN in clinical practice requires significant technical training using a variety of tools. Over recent years, a range of surgical training methods have been used to teach surgeons how to apply laparoscopic techniques, including dry boxes, artificial anatomical models, and live animals (14). However, these methods do not allow surgeons to master the techniques that are unique to ELPAN owing to significant differences in anatomy. These critical limitations could be avoided by utilizing cadavers for surgical training in ELPAN techniques. The preparation and establishment of a pneumoperitoneum in the retroperitoneal space are essential for ELPAN training. To meet this requirement, it is essential that the cadavers to be used for ELPAN training are fixed in a manner that preserves the elasticity and toughness of the tissues, especially the peritoneum.

Thiel's embalming method, first described by Walter Thiel in 1992, generates cadavers with sufficient flexibility and a color tone that is similar to that of a living body (12,13), thus representing a vital resource for surgical training. Our current analysis confirmed that a Thiel-embalmed cadaver could be used to successfully reproduce the ELPAN technique. Notably, the detachment of the peritoneum, the expansion of the retroperitoneal cavity, and the generation of a pneumoperitoneum could be reproduced in a Thiel-embalmed cadaver with the same tactile sensations as in a living body. However, Thiel fixation caused the great vessels to collapse and lose their elasticity. Thus, the condition of the vascular tissue was not maintained at the same level as other tissues. Therefore, we were unable to perform training in vascular suturing due to the fragility of the vein walls. Therefore, it may be more efficient to use live animals when training surgeons to control venous bleeding. It is important that future research aims to develop a range of training models, incorporating cadavers and other models, to generate a range of options for surgical training.

In conclusion, Thiel-embalmed cadavers represent an efficient tool for ELPAN training as the condition of the tissue is maintained in a manner that is very similar to that of a living body. Furthermore, the tactile sensations provided by these cadavers are almost identical to those experienced by surgeons in clinical practice. Therefore, surgical training using a Thiel-embalmed cadaver can be considered as a valuable tool for learning the surgery associated with the ELPAN technique. We have used the ELPAN technique in more than 20 patients with early-stage endometrial cancer at our institution with no complications or other concerns. We aim to conduct regular surgical training sessions on the ELPAN technique using Thiel-embalmed cadavers to improve the surgical skills of our surgeons and hope that this training technique will be adopted by other institutions.

Acknowledgements

Not applicable.

Funding

No funding was received.

Availability of data and materials

The data generated in the present study are not publicly available, because images of surgical training using cadavers are not allowed to be published, but may be requested from the corresponding author.

Authors' contributions

This study was conducted as part of a cross-disciplinary cadaver-based surgeon education program designed by AK. HM designed the study as head of the obstetrics and gynecology section of the program. SN and KI designed the outline of the study and managed the overall study. SN, KI, KK and NI conducted the study under the guidance of MA. MA designed the surgical training procedures, conducted the training, and analyzed the data. TKo and TKa prepared the cadavers in advance and assisted with the study progress on the day of training. SN wrote the manuscript, and all authors discussed the results and commented on the manuscript. SN and KI confirm the authenticity of all the raw data. All authors read and approved the final version of the manuscript.

Ethics approval and consent to participate

This surgical training project, involving cadavers, was performed in accordance with the guidelines described in the Declaration of Helsinki, and was approved by the Institutional Review Board of Okayama University (approval number: K1608-004; Okayama, Japan). Written informed consent was obtained from each donor before their death.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

References

1. Todo Y, Kato H, Kaneuchi M, Watari H, Takeda M and Sakuragi N: Survival effect of para-aortic lymphadenectomy in endometrial cancer (SEPAL study): A retrospective cohort analysis. Lancet 375: 1165-1172, 2010.
2. Vasilev SA and McGonigle KF: Extraperitoneal laparoscopic paraaortic lymph node dissection: Development of a technique. J Laparoendosc Surg 5: 85-90, 1995.
3. Querleu D, Dargent D, Ansquer Y, Leblanc E and Narducci F: Extraperitoneal endosurgical aortic and common iliac dissection in the staging of bulky or advanced cervical carcinomas. Cancer 88: 1883-1891, 2000.
4. Prodromidou A, Machairas N, Spartalis E, Kostakis ID, Iavazzo C, Moris D, Tsilimigras DI, Athanasiou A and Nikiteas N: Transperitoneal versus extraperitoneal laparoscopic lymphadenectomy for gynecological malignancies: A systematic review and meta-analysis. Anticancer Res 38: 4677-4681, 2018.
5. Ferron G, De Santiago J, Querleu D, Martinez A, Angeles MA, Boulet B, Guyon F and Zapardiel I: Left lateral endosurgical extraperitoneal total hysterectomy with para-aortic and pelvic lymphadenectomy: A novel approach for the obese patient with endometrial cancer. J Minim Invasive Gynecol 25: 730-736, 2018.
6. Zhang W, Xia L, Han X, Ju X, Wu X and Chen X: Extraperitoneal laparoscopy for para-aortic lymphadenectomy in endometrial carcinoma staging: An approach with higher efficiency. World J Surg Oncol 19: 323, 2021.
7. Li KP, Deng XZ and Wu T: Surgical outcomes of transperitoneal para-aortic lymphadenectomy compared with extraperitoneal approach in gynecologic cancers: A systematic review and meta-analysis. Front Surg 8: 779372, 2021.
8. Morice P, Joulie F, Camatte S, Atallah D, Rouzier R, Pautier P, Pomel C, Lhommé C, Duvillard P and Castaigne D: Lymph node involvement in epithelial ovarian cancer: Analysis of 276 pelvic and paraaortic lymphadenectomies and surgical implications. J Am Coll Surg 197: 198-205, 2003.
9. Michel G, Morice P, Castaigne D, Leblanc M, Rey A and Duvillard P: Lymphatic spread in stage Ib and II cervical carcinoma: anatomy and surgical implications. Obstet Gynecol 91: 360-363, 1998.
10. Yoshida H, Yamamoto M and Shigeta H: Learning curve of laparoscopic extraperitoneal para-aortic lymphadenectomy for endometrial carcinoma: A cumulative sum analysis. Surg Oncol 35: 254-260, 2020.
11. Morizane S, Honda M, Kihara K, Yamamoto M, Komatsu H, Sato S, Hikita K, Tanishima S, Nakane H, Kurosaki M, *et al*: Laparoscopic pelvic lymph node dissection in cadaver surgical training from the combined perspectives of urologists, gastroenterologists and gynecologists improves overall knowledge and technique: Initial experience of multidisciplinary cadaver surgical training at a single institution in Japan. Anat Sci Int 97: 303-306, 2022.
12. Hammer N: Thirty years of thiel embalming-a systematic review on its utility in medical research. Clin Anat 35: 987-997, 2022.
13. Rakuša M and Kocbek Šaherl L: Thiel embalming method used for anatomy dissection as an educational tool in teaching human anatomy, in research, and in training in comparison of different methods for long term preservation. Folia Morphol (Warsz) 82: 449-456, 2023.
14. Usami T, Fujioka T, Yoshida A, Miyaue H, Yasuoka T, Uchikura Y, Takagi K, Matsubara Y, Matsumoto T, Matsubara K and Sugiyama T: Assessment of laparoscopic training for gynecological malignancies using Thiel-embalmed human cadavers. Mol Clin Oncol 9: 511-514, 2018.