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Analysis of the Effect of Structured Training of Total Pelvic Exenteration Based on Anatomical Operation of Frozen Cadaver Specimens

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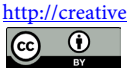

Abstract

Objective: To analyze the effect of structured training of total pelvic exenteration (TPE) based on the anatomical operation of fresh-frozen cadaveric specimens. **Methods:** A questionnaire survey was conducted among 24 participants who participated in the fourth phase of the "Everest Project" in October 26-28, 2023—Total Pelvic Organ Excision Surgery Master Class, and the knowledge acquisition and course evaluations before and after the training were counted. **Results:** Before and after the training, the students' self-confidence in surgical anatomy (4.38 ± 1.38 vs 5.83 ± 1.52 points), surgical procedures (3.58 ± 1.25 vs 4.83 ± 1.27 points), theoretical level of self-evaluation of training effect (4.83 ± 1.55 vs 6.25 ± 1.54 points) and operational ability (4.33 ± 1.09 vs 5.29 ± 1.55 points) showed statistically significant improvements ($P < 0.05$). **Conclusion:** The structured training based on the anatomical operation of fresh-frozen cadaveric specimens is a new attempt for TPE, a difficult surgical training method. The structured training is practical and feasible, which can improve the safety, standardization and effectiveness of TPE. The structured training is practical and feasible, and it appears to enhance the standardization and effectiveness of TPE.

Keywords

Total Pelvic Exenteration, Structured Training, Frozen Cadaver Specimens, Dissection, Questionnaires, Course Evaluations

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1. Introduction

Total pelvic exenteration (total pelvic exenteration, TPE) refers to the radical resection of multiple pelvic organs for locally advanced or recurrent tumors in the pelvic cavity, including the removal of gynecologic organs, urinary organs, and relevant portions of the gastrointestinal tract [1]. TPE requires multidisciplinary collaboration among colorectal surgeons, urologists, and gynecologists. Surgeons must possess interdisciplinary skills, and the procedure is associated with high rates of postoperative complications and mortality, making practitioners reluctant to perform it; both domestically and internationally, TPE is limited to a few large medical centers [2]. Therefore, there is an urgent need for structured training in relevant surgical techniques. Currently, cadaveric surgical skills training using fresh-frozen specimens is considered the "gold standard" for surgical skills training [3] [4]. Compared to formalin-fixed cadavers, fresh-frozen specimens preserve the color and texture of vessels, muscles, fascia, and internal organs much better, more closely simulating real intraoperative conditions in humans, and thus offer significant advantages for surgical training. Drawing upon this advantage, a structured TPE training program based on procedural dissection of fresh-frozen cadaveric specimens was designed and implemented. This study analyzes and summarizes the outcomes of this training program among its participants.

2. Data and Methods

2.1. Study Participants and Data Collection

Trainees from the fourth session of the "Everest Project" Total Pelvic Exenteration Surgical Masterclass (held October 26-28, 2023) were eligible if they completed the full training course. Demographic information (years since graduation, prior experience with TPE surgery) and course completion status were recorded using a standardized form.

2.2. Methods

Preparatory work: To assess the feasibility of the training, a trial TPE procedure was performed on a formalin-fixed cadaver specimen. Based on this experience, a training curriculum was developed, and relevant textbooks, literature, and surgical videos of TPE were prepared to support the actual training.

Experimental materials: fresh-frozen cadaveric specimens were provided by the Department of Human Anatomy at Suzhou Medical College of Soochow University and thawed one day in advance. Six cadaver specimens were used for this training. Surgical instruments included a cutting and closure device, Hemlock clips (provided by Fenghe Company), suction apparatus, masks, disposable surgical gowns, and other related items.

All participants completed every training module. Following the conclusion of the training program, the research team distributed a survey via WeChat, with its design and collection conducted through the Wenjuanxing platform. The survey

primarily assessed participants' understanding of knowledge related to TPE surgery, identification of key anatomical structures, and management of TPE-related complications.

Before the training began, trainees were first required to study professional books, literature, and utilize pelvic floor models and other teaching tools to learn and understand pelvic floor anatomy. Two experienced domestic TPE experts each conducted a surgical demonstration. The first case involved a 56-year-old female, four years post-rectal cancer surgery, diagnosed with recurrence for nearly one year. The recurrent rectal tumor invaded the presacral fascia, perineum, and left gluteus maximus, with possible invasion of the posterior bladder wall and vagina. The procedure performed was total pelvic exenteration (resection of pelvic tumor + partial bladder + vagina + sacral segments 4 - 5 + pelvic floor muscles and part of the gluteus maximus) + reconstruction of the posterior peritoneum and pelvic floor muscle with a basement membrane biological patch + pedicled omental flap to fill the pelvic cavity to prevent empty pelvis syndrome + urinary tract reconstruction. The second case was a 37-year-old female who, two and a half years after comprehensive treatment for rectal cancer, was diagnosed with recurrence in the right rectal wall and presacral area, with possible invasion of the right pelvic floor fascia and vaginal posterior wall. She underwent a modified Bacon procedure combined with resection of right pelvic and partial vaginal tumor, with creation of a single-lumen transverse colostomy. Surgeons focused on key pelvic floor anatomy, including the sacral nerves, sciatic nerve, internal iliac vessels and all branches, sacral nerve roots, presacral fascia, and pelvic floor muscles. They also demonstrated key TPE techniques: en bloc lateral pelvic resection, presacral fascia resection, sacrectomy, and the management of complex pelvises (**Figure 1**).

Fresh cadaveric specimen surgical training: Three instructors and 24 trainees participated in surgical training in the specimen operating room of the Institute of Clinical Anatomy, Suzhou Medical College of Soochow University. All three instructors were renowned domestic experts with extensive TPE experience. Surgical instruments and consumables identical to those used in real operations were employed. Prior to trainee participation, the instructors demonstrated procedural steps, technical aspects, and identification of key anatomical structures, after which the trainees performed the procedures in rotation (**Figure 2**).

2.3. Observation Indicators

After the training, a survey was distributed via WeChat Wenjuanxing, collecting responses from trainees regarding their self-assessed confidence before and after the training in "surgical anatomy", "surgical procedures", and "management of complications", as well as the training effectiveness in "theoretical knowledge" and "practical skills" across a total of five dimensions. Each dimension was scored from 0 to 10 points. Additionally, the questionnaire concluded with an open-ended question to gather trainees' opinions and suggestions on the training, including but not limited to aspects such as format, methodology, and content. All

items in the questionnaire are shown in the supplementary file.

2.4. Statistical Methods

After data collection, analysis was performed using SPSS 22.0 statistical software. Categorical data are presented as percentages (%), while continuous data, specifically the trainees' scores before and after structured training, are expressed as mean ± standard deviation ($\overline{x} \pm s$). An independent samples t-test was used. A P-value of less than 0.05 was considered statistically significant.

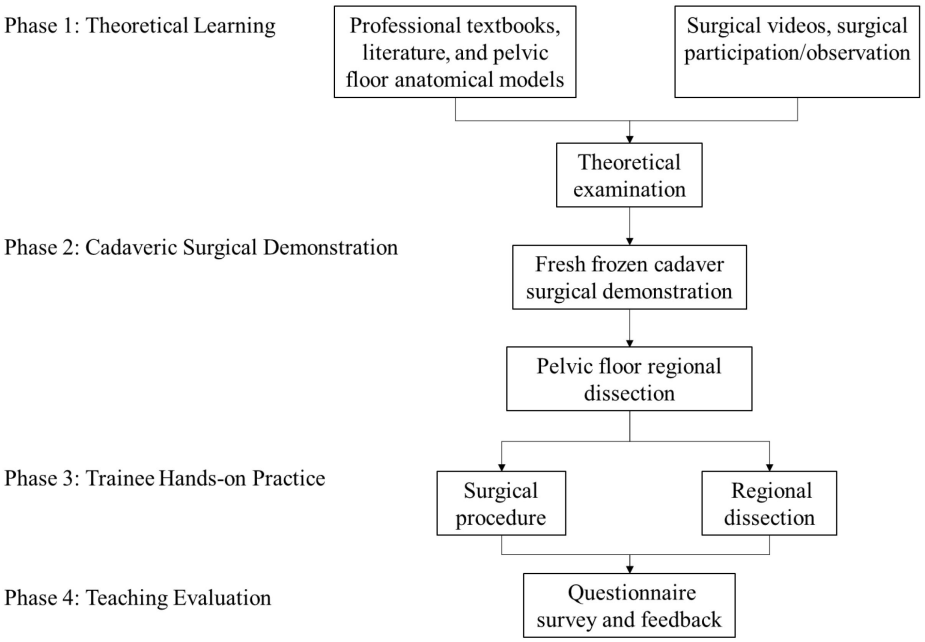

Figure 1. Flowchart of the structured training process.

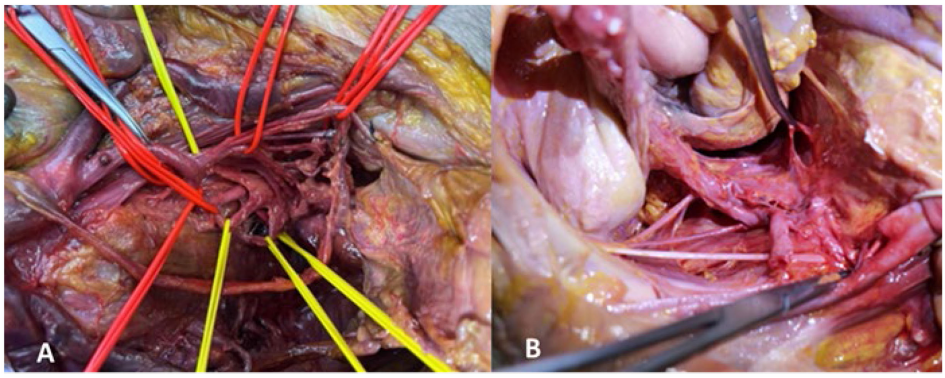

Figure 2. Anatomical appearance of fresh frozen gross specimens (A: internal iliac vessels and their branches; B: presacral fascia).

3. Results

3.1. Participant Characteristics and Course Completion

A total of 24 trainees from 23 hospitals across 16 provinces/municipalities in

China were included. The mean time since graduation was 15.34 years. Prior to the training, three trainees (12.50%) had experience with TPE surgery. The overall course completion rate was 95.83% (23/24); one trainee was unable to tolerate the anatomy session and did not participate in the entire anatomical training.

3.2. Analysis of Trainee Training Effectiveness

All 24 questionnaires were collected, resulting in a response rate of 100%. 21 participants (87.50%) believed that the structured training was helpful for understanding TPE anatomy; 22 participants (91.67%) felt that it was beneficial for their subsequent independent performance of TPE; 19 participants (79.17%) considered the structured training helpful for managing postoperative complications of TPE; and 16 participants (66.67%) expressed an intention to carry out TPE procedures at their respective institutions.

After training, participants' confidence scores in TPE surgical anatomy, confidence scores in surgical steps, self-assessed theoretical knowledge, and self-assessed operative skills were all significantly higher compared to before training ($P < 0.05$). There was no statistically significant difference in confidence scores for complication management before and after training ($P > 0.05$), as shown in Table 1.

Table 1. Comparison of confidence level scores and training outcomes before and after trainee training (score, $\overline{x} \pm s$).

	Confidence level score ($\overline{x} \pm s$)			Self-evaluation of post-training outcomes ($\overline{x} \pm s$)	
	Surgical anatomy	Surgical procedure	Management of complications	Theoretical level	Operational capability
Before training	4.38 ± 1.38	3.58 ± 1.25	3.88 ± 1.23	4.83 ± 1.55	4.33 ± 1.09
After training	5.83 ± 1.52	4.83 ± 1.27	4.25 ± 1.07	6.25 ± 1.54	5.29 ± 1.55
t	−3.460	−3.437	−1.111	−3.184	−2.482
P	0.001	0.001	0.266	0.003	0.017

3.3. Opinions and Suggestions from Trainees Regarding the Training

This open-ended question received feedback from 16 participants. They noted that "the instruction during cadaveric dissection was detailed and engaging," "the selected theoretical textbooks are classic and authoritative", "the surgical videos produced were very clear, with procedures demonstrated in accordance with anatomical principles", "the relevant surgical techniques are highly practical", "the understanding of total pelvic exenteration has become more systematic, comprehensive, and in-depth", "a textbook or professional book could be published", "there is a hope for more similar training sessions to provide additional learning opportunities", "it would be best to participate directly in surgery for a more intuitive experience", "course videos should be made available for repeated learn-

ing", "the explanation of presacral vessel management was very detailed", "a separate session on imaging interpretation could be added", "there could be more instruction on analyzing classical cases, explaining how to select the surgical approach and design the operative procedure", and "there should be an introduction to total pelvis surgical instruments and operating room setup requirements". At the same time, three participants remarked, "The course content is rather advanced for physicians who have not performed total pelvic exenteration", and "the distinction between blood vessels and nerves in the gross specimens is not clear".

4. Discussion

TPE was first applied by Brunschwig at Memorial Hospital in New York in 1948 as a palliative surgical treatment for advanced and recurrent cervical cancer [5]. In the following decades, various centers (primarily in the United States) gradually extended the use of this novel procedure, TPE, to the treatment of other malignancies such as rectal cancer [6]-[8], vulvar cancer [9] [10], ovarian cancer [11] [12], prostate cancer [13] [14], and pelvic sarcoma [15]. TPE is a complex surgery involving multiple systems and requires urinary reconstruction, stoma creation, and flap transplantation, resulting in high complication and mortality rates [16] [17]. Moreover, TPE is costly, with reports indicating an average cost of up to $30,720 for TPE procedures abroad [18], thus only a limited number of centers and institutions regularly perform this operation both domestically and internationally. The anatomical structures involved in this procedure, such as the anterior and posterior branches of the internal iliac artery, lateral pelvic structures, presacral fascia, sacrum, sciatic nerve, femoral nerve, piriformis, and pelvic floor muscles, are rarely encountered in routine colorectal surgery. Therefore, surgeons not performing TPE find it difficult to learn these anatomical details in routine practice, and even during TPE procedures, it is challenging to fully expose the branches of the internal iliac artery and lateral pelvic anatomy. Hemorrhage is one of the most common complications of TPE [19]-[21]; the internal iliac vessels and their branches are major arterial supplies to the pelvic organs, with considerable variation in origin and branching patterns, and the communicating branches of the internal iliac vessels as well as the presacral venous plexus are major sources of bleeding during total pelvic exenteration. The course and anatomical features of these vessels are difficult to fully master through routine surgery or theoretical study. TPE emphasizes en bloc resection of the rectum, bladder, lower ureters, and internal genital organs (including the seminal vesicles and prostate in males, and the uterus and vagina in females). The key to surgical success lies in achieving an R0 margin, which is an independent prognostic factor for oncological outcome [22]. The fascial spaces within the pelvis provide the basis for surgical anatomy, including the retropubic, retrorectal, presacral, vesicocervical, vesicovaginal, and ureterovaginal spaces. In the complex context of TPE, accurate knowledge of these spaces is required to identify the correct surgical planes and achieve R0 resection [23], which necessitates specialized training in the relevant anatomical spaces.

At present, there have been reports both domestically and internationally on the use of structured cadaveric training for transanal pelvic exenteration surgery [24] [25], transanal total mesorectal excision (TaTME) [26], bariatric metabolic surgery [27], as well as gynecological procedures [28] [29], among others. However, there are no reports in either domestic or international literature of surgical training specifically targeting TPE. Therefore, our center drew on the structured surgical training experiences of other centers, both in China and abroad. The content of these structured training courses generally includes theoretical learning, live surgical demonstrations, cadaveric specimen-based surgical training, and questionnaire surveys, among which cadaveric specimen dissection and surgical training are the most crucial components. Compared to anatomical models, atlases, surgical videos, and virtual reality technologies, cadaveric dissection offers advantages in realism, three-dimensionality, and operability, making it the most effective approach for mastering anatomical knowledge. Compared with embalmed cadavers, fresh-frozen cadaveric specimens maintain anatomical structures that most closely resemble the actual intraoperative state, and in comparison to animal models and other simulation methods, best replicate real clinical surgery. However, due to the influence of traditional cultural beliefs, the domestic body donation rate is much lower than in developed countries such as those in Europe and North America, leading to a scarcity of cadaveric specimens, with fresh-frozen cadaveric specimens being even rarer [30] [31]. Based on our center's expertise in TPE surgery, we designed a structured training program for total pelvic exenteration based on fresh-frozen cadaveric anatomical operations, integrating both theory and practical training. Senior and mid-career surgeons from 16 provinces and cities across China participated actively and showed strong interest in learning. Questionnaire results after the training indicated that 66.67% of participants intended to perform TPE at their own institutions, demonstrating the significant value of this structured training. Self-assessments of participants before and after the training showed statistically significant improvements in surgical anatomy, surgical procedures, theoretical knowledge, and operative skills ($P < 0.05$); however, there was no statistically significant difference in complication management ($P > 0.05$). This lack of improvement is likely attributable to specific limitations of the cadaveric specimens used in the training. While fresh-frozen specimens generally mimic intraoperative anatomy, they are subject to vascular collapse and incomplete thawing—issues that directly compromise the realistic simulation of complication scenarios. For example, collapsed veins and arteries cannot be reliably clamped or sutured, and incompletely thawed tissues exhibit abnormal friability and poor handling characteristics. As a result, trainees are unable to practice critical steps such as controlling hemorrhage from a torn vessel or managing intraoperative bleeding under realistic tension. Consequently, even though the structured training improved other outcomes (surgical anatomy, procedures, theoretical knowledge, operative skills), the specific domain of complication management remained difficult to teach or assess effectively using these

suboptimal specimens. To overcome this limitation, future training should prioritize specimens with optimal vascular integrity and uniform thawing, supplemented by fresh cadaveric or perfused models, as well as clinical fellowships that allow trainees to observe and participate in real-time management of TPE complications.

There were still some shortcomings in this training. Although one day was allocated for specimen thawing before the training, incomplete thawing occurred in some cases—possibly due to the cold weather, the large number of pelvic organs, and the presence of bladders containing frozen urine—resulting in difficulties during anatomical and surgical procedures. Vascular collapse in the specimens often led to vessel rupture during operation, making it impossible to trace their branches and complete structures. After consulting with experts from the Department of Anatomy, this issue can be addressed by perfusing colored colloids into the arteries and veins. Due to the obstruction caused by pelvic bony structures and the positioning of the specimens, visual blind spots arose when exposing lateral pelvic structures and branches of the internal iliac vessels, making full visualization challenging. Experts suggested that preparing one-quarter pelvic bone anatomical specimens could solve this problem. As this was the first large-scale structured anatomical training conducted by our center, the preliminary training objectives were achieved; however, due to the limited follow-up period, there are no clinical data yet on trainees performing TPE at their respective institutions after the training. Our center will summarize and optimize the experiences from this training, continue to organize larger-scale training sessions, and conduct follow-up surveys to evaluate the practical significance of structured training using fresh-frozen cadaveric specimens for TPE clinical procedures and the prevention and management of surgical complications. Additionally, the evaluation of training outcomes in this study relied solely on participants' subjective self-assessments. No objective skill verification (e.g., expert grading of cadaveric dissection quality, or a validated objective structured assessment of technical skills [OSATS]) was performed. This limits the ability to confirm whether the self-perceived improvements correspond to actual technical competence.

The teaching of complex surgical procedures and the dissemination of related techniques are responsibilities and obligations of large tertiary teaching hospitals. TPE represents the only curative option for patients with locally advanced or recurrent pelvic malignancies; however, few institutions in China routinely perform this procedure. Our center has developed a structured training program utilizing anatomical dissection of fresh-frozen cadaveric specimens, which has proven effective in promoting the adoption of this surgery. Through further optimization of course design and the regular implementation of large-scale training sessions, more surgeons specializing in colorectal surgery, urology, gynecologic oncology, and other disciplines related to whole-pelvic surgery can benefit. This approach enables participants to rapidly master the key anatomical features, technical challenges, and strategies for the prevention and management of complications asso-

ciated with TPE, thereby advancing the development of TPE procedures in China.

This study analyzes the outcomes of the October 2023 total pelvic organ excision training program, revealing that participants demonstrated increased confidence in TPE anatomy, procedural steps, theoretical knowledge, and operative skills following the training, indicating significant educational benefits. The results confirm that the program provides practical and effective training for TPE surgery. Additionally, areas such as curriculum design and follow-up tracking of participants could be further optimized to achieve improved training outcomes.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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