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Comparative study to determine the proper sequence of simulation training, pelvic trainer versus virtual reality simulator: a pilot study

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Abstract

Background Increased surgical efficacy has led to a remarkable increase in the usage of minimally invasive surgical procedures since their inception. The use of simulation in surgical teaching has grown significantly during the past 10 years. Several laparoscopic simulators have been built. Virtual reality (VR) simulators and box trainers (BTs), often known as pelvic trainers, are the two primary training modalities used in hospitals and clinical training institutes for the development and acquisition of laparoscopic skills. Our study aimed to evaluate the proper sequence of pelvic trainers and VR simulator training to improve laparoscopic gynecological skills.

Methodology We carried out this pilot study at the Virtual Endoscopic Simulation and Skills Acquisition Laboratory at the Obstetrics and Gynecology Department in the Kasr Al Ainy Hospital, Faculty of Medicine, Cairo University, Egypt, from February to August 2022. All residents with minimal or without laparoscopic experience (twenty residents) were divided into two groups and classified as (group A versus group B). Group A's training began with a pelvic trainer, which was tested using a checklist. Later, the group trained on a virtual reality simulator, which tested them using an electronic autoassessment. After training on a virtual reality simulator and passing an electronic autoassessment test, group B moved on to pelvic trainers and had a checklist-based assessment.

Results We compared pelvic trainer tasks between the training groups, and detected no significant differences in camera navigation, cutting pattern, peg transfer, or running stitches (*P* values 0.646, 0.341, 0.179, and 0.939 respectively); when we compared VR simulator tasks between the training groups, there were no significant differences in camera navigation, cutting pattern, peg transfer, or running stitches (*P* values 0.79, 0.3, 0.33, and 0.06, respectively).

Conclusion There was no difference in training, between residents who started on a pelvic trainer or the VR simulator; therefore, both could be used in laparoscopic training with no preferred order.

Trial registration The trial was registered at clinicaltrials.gov with the name "Pelvic trainer vs VRS" and the identifier "NCT05255614." The registration date was January 19, 2022, and the trial was prospectively registered. URL: https://register.clinicaltrials.gov/prs/app/action/ViewOrUnrelease?uid=U0004GED&ts=22&sid=S000BR5D&cx=t6mc14

Keywords Pelvic trainer, Simulation training, Virtual reality simulator

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Background

Increased surgical efficacy has led to a remarkable increase in the usage of minimally invasive surgical procedures since their inception. However, these techniques have increased the level of expertise needed to perform safe and effective surgical procedures. Surgeons must learn how to deal with issues including diminished haptic feedback from instruments and poor depth perception from 2D displays [1]. In order to get around these challenges, more focus is being placed on simulation-based education to build fundamental skills for laparoscopic surgery [2]. Laparoscopic training platforms known as box trainers or pelvic trainers have been created by a number of manufacturers, and these platforms have simple designs that include a box with holes for trocar insertion, simulating the insufflated abdominal cavity. Five of the initial seven tasks are included in it: peg transfer, accurate cutting, ligating loop placement and securing, simple suturing with an extracorporeal knot, and simple suturing with an intracorporeal knot. Of these five tasks, intracorporeal suturing is the most difficult to perfect technically. Even for highly skilled surgeons, learning intracorporeal suturing and knot tying is regarded as one of the most challenging surgical procedures [3].

To simulate the virtual versions of the FLS tasks, an advanced virtual laparoscopic skill trainer was created that includes automated, real-time performance evaluation and feedback. Real-time virtual simulation of various gynecologic endoscopic procedures can be facilitated by adding more modules. With its haptic feedback feature, which enables accurate feelings, this VR simulator offers unlimited training without required consumables. Moreover, they are able to offer prompt, unbiased comments on the trainee's performance. Furthermore, studies have demonstrated the efficacy of virtual reality simulator training in the acquisition of laparoscopic surgical skills [2].

Our study aimed to evaluate the proper sequence of pelvic trainers and VR simulator training to improve laparoscopic gynecological skills, as we believed that training on both is essential to achieve competence in basic laparoscopic skills.

Methodology

Study design

This pilot study was a small preliminary study intended to assess feasibility and inform a future full-scale trial. It was carried out from February to August 2022 in the Virtual Endoscopic Simulation and Skills Acquisition Lab at Kasr Al Ainy Obstetrics and Gynecology Department, Faculty of Medicine, Cairo University, Egypt, among all the residents in our department who had little or no experience with laparoscopic procedures (convenient sample). The *inclusion criteria* included residents with no or little previous laparoscopic experience, who have basic knowledge about laparoscopy, no or little previous experience with laparoscopic simulators, who observed at least one laparoscopic surgery at the theater, and ages ranging from 26 to 29 years old. The *exclusion criteria* included residents who were not interested in laparoscopic training and who could not attend all the training sessions. Twenty residents were divided into two groups:

➢ Group A: Ten residents began training on a pelvic trainer (training on educational intervention 1), were assessed using a checklist (test 1), then they trained on a VR simulator (training on educational intervention 2) and were assessed via an electronic autoassessment by the simulator (test 2).

➢ Group B: Ten residents began their training on VR simulation (training on educational intervention 2) and were assessed via an electronic autoassessment by the simulator (test 2), then were trained on a pelvic trainer (training on educational intervention 1) and were assessed using a checklist (test 1).

Assessment and training tasks

Training schedule

Participants practiced for one session a day, 1 day a week, for three consecutive weeks. According to their group assignments, they performed three training sessions on the VR simulator (LapSim) or the pelvic trainer.

Pelvic trainer We used Lap. -Trainer, the SZABO-BERCI-SACKIER model, that was constructed by KARL STORZ. SE & Co. KG in Germany (Figs. 1 and 2). The curriculum designed for the pelvic trainer simulator included four tasks: camera navigation, cutting pattern, peg transfer, and running stitches. Participants were assessed after three training sessions using a checklist.

All four pelvic trainer tasks are described briefly below:

- *Camera navigation:* Participants were required to hold the camera with their nondominant hand while the dominant hand held the light source. The camera was then navigated using a light source to find the alphabet or number, which appeared at various locations on the wooden boards. Sequentially, focus on and locate the alphabet or the number within the circle on the computer screen. The procedure continues until the N alphabet is reached, which is the end. Performance was measured by the score percentage of hand–eye coordination, bimanual coordination, the number of errors associated with the centering of the field to find the alphabet or number, the maintenance of the correct horizon angle while performing camera navigation, and the time required to complete the task (Fig. 3).
- *Peg transfer:* A grasper held by the participants' nondominant hand lifted a peg to transfer it to the

Fig. 1 Pelvic trainer

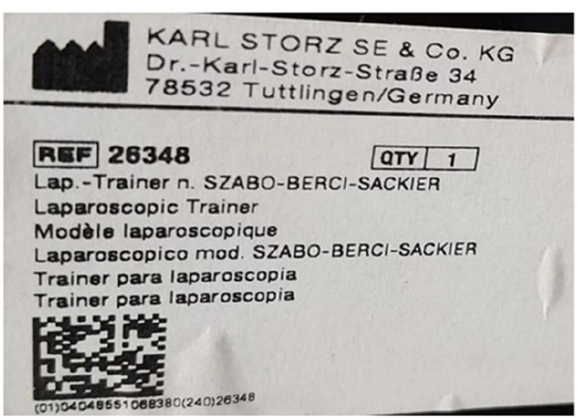

Fig. 2 Pelvic trainer model

grasper held by the dominant hand and then placed it on the opposite side of the board. After all, six pegs were transferred, and this time, the process was repeated, starting with the dominant hand. Performance was measured by the percentage of pegs dropped, hand–eye coordination, bimanual coordination, the time required to complete the task, and the number of failures in transferring the pegs (Fig. 4).

Fig. 3 Camera navigation. It shows the camera navigation task by the pelvic trainer

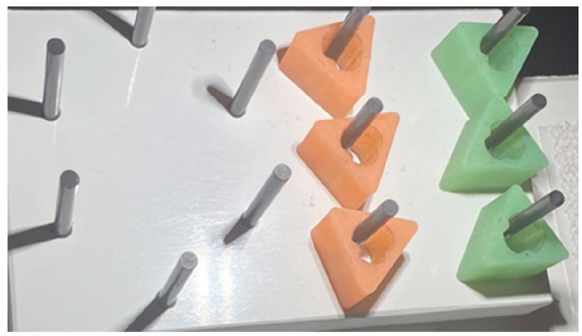

Fig. 4 Peg transfer. It shows the peg transfer task by the pelvic trainer

- *Cutting pattern:* A square piece of gauze was suspended between clips in the center of the field. A circle was cut on marked gauze with one hand using laparoscopic scissors, while the other held a grasper that was used to place the gauze at optimal angles for cutting. Performance was measured by the percentage of unsuccessful cutting attempts, the percentage of the cutting part of the boundary area, hand–eye coordination, bimanual coordination, and the time required to complete the task (Fig. 5).
- *Running stitches:* The longitudinal piece of a mattress, which was suspended between clips, was marked with six dots. Running stitches were made on marked dots with one hand using a needle holder and the other holding the graspers until the last dots were stitched. Performance was measured by the percentage of the number of times the needle was picked up in the correct orientation to make a bite, the number of successful attempts to pass the needle through two edges of tissue with appropriate bite placement and

Fig. 5 Cutting pattern. It shows the cutting pattern task by the pelvic trainer

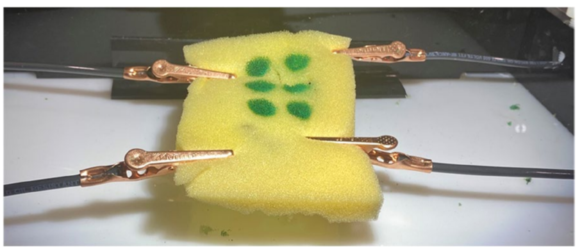

Fig. 6 Running stitches. It shows the running stitches task by the pelvic trainer

tissue handling, hand–eye coordination, bimanual coordination, and the time required to complete the task (Fig. 6).

LapSim (virtual reality simulator) LapSim is a device designed by Surgical Science Device and Software in Sweden, and we used the TP100 model made by KARL STORZ. SE & Co. KG in Germany (Figs. 7 & 8). The curriculum developed for this simulator included four tasks: camera navigation, cutting pattern, peg transfer, and running stitches. Participants were assessed after three sessions of training via an electronic auto assessment by the VR simulator.

All four LapSim tasks are described briefly below:

- *Camera navigation:* Participants were instructed to use the central instrument to navigate the camera to locate four gallstones that appeared on the tissue surface, zoom in on them to match their size to the on-screen circle, and hold the camera steadily until the gallstones disappeared. The performance metrics included camera handling, hand–eye coordination, the number of errors associated with cen-

Fig. 7 LapSims

Fig. 8 LapSims model

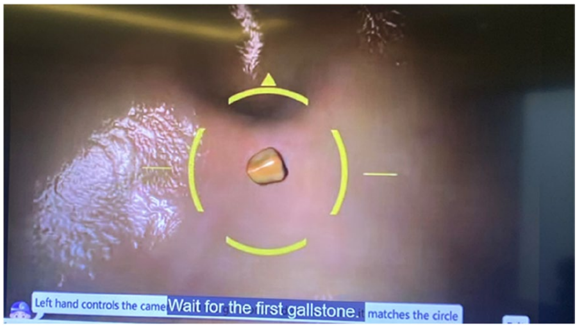

Fig. 9 Camera navigation. It shows the camera navigation task by the LapSims

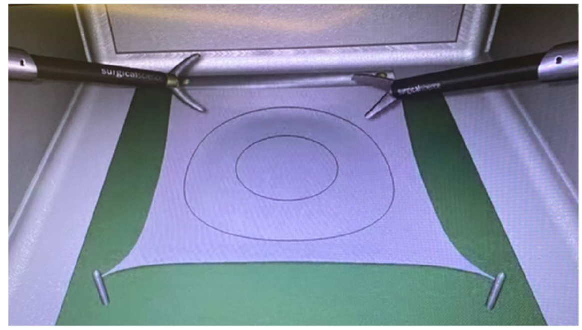

Fig. 11 Cutting pattern. It shows the cutting pattern task by the LapSims

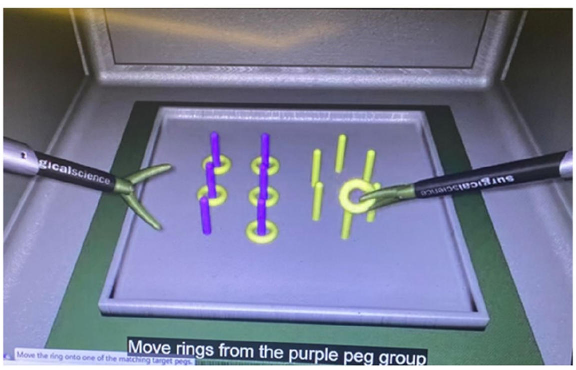

Fig. 10 Peg transfer. It shows the peg transfer task by the LapSims

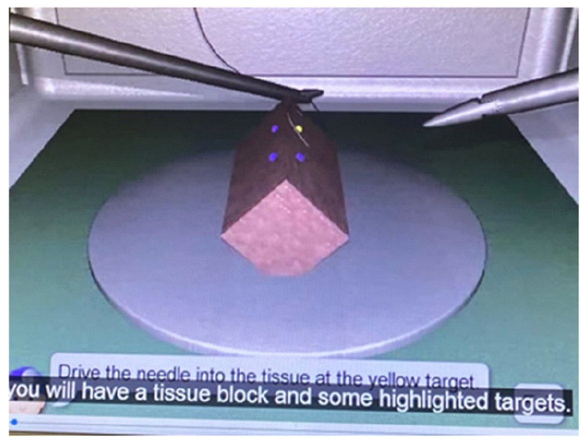

Fig. 12 Running stitches. It shows the running stitches task by the LapSims

tering the field while zooming in on the gallstone, and maintaining the correct horizon angle while performing camera navigation (Fig. 9).

- *Peg transfer:* Participants needed to move rings from the purple peg group by using a grasper with the nondominant hand, transfer that peg to the grasper held by the dominant hand, and subsequently place it on the green peg group. When all six rings have been transferred back and forth between the peg groups, the exercise will end. The performance metrics included the number of pegs dropped, instrument path length, hand–eye coordination, bimanual coordination, the time required to complete the task, and the number of failures in transferring the pegs (Fig. 10).
- *Cutting pattern: The* participants needed to grasp the cloth in the center with a grasper and start cutting inside the region confined by the two contours. When the participant successfully cut around the contour, the exercise ended. The performance metrics included percentage of cuttings out of the boundary area, the number of unsuccessful cutting attempts, the instrument path length, the hand–eye coordination, the bimanual coordination, and the time required to complete the task (Fig. 11).
- *Running stitches:* Participants were required to pull back both right and left instruments to start the exercise. Then, the needle needs to drive into the tissue at the yellow target. When stitches are applied to tissue, the participant needs to pull the needle entirely to reach the next target to be highlighted. The performance metrics included the following: picking up the needle in the correct orientation to make a bite, passing the needle through two edges of tissue with appropriate bite placement and tissue handling, hand–eye coordination, bimanual coordination, and the time required to complete the task (Fig. 12).

Test 1 We could not find a checklist made by previous research, so we made a checklist that included the same items used in the VR simulator for the autoassessment for each task to be more valid and reliable. Our senior author who is the head of the minimally invasive surgery department and has more than 10 years of experience in laparoscopic surgery observed each candidate while performing the task, giving a score of 100 for each item on the checklist; subsequently, we calculated the mean score of 100. The checklist assessment for each task performance included the items that had already been mentioned before for each task.

Test 2 Electronic autoassessment by the VR simulator and a score of 100 for each candidate. The autoassessment for each task included the performance metrics that had been previously mentioned for each task.

The primary outcome was to evaluate the proper sequence of pelvic trainer and VR simulator training to improve laparoscopic gynecological skills. The secondary outcome was laparoscopic training for residents with no previous laparoscopic experience.

Sampling type, technique, and size Since this was a pilot study, the sample size was not estimated. The purpose of the sample size was to determine feasibility and give preliminary data to guide larger-scale trials in the future; therefore, we used a convenient nonprobability sample. We included all the residents with little or no laparoscopic experience in Kasr Al Ainy Obstetrics and Gynecology Department, who were registered during the period from February to August 2022.

Statistical analysis

All the collected data were revised for completeness and logical consistency. Precoded data were entered into a computer using the Microsoft Office Excel Software Program 2019. Precoded data were subsequently transferred and entered into the Statistical Package for Social Science Software program (SPSS), version 26, for statistical analysis. The data are presented as the mean, standard deviation, median, and interquartile range (IQR). The variables were compared using the Mann–Whitney U test, where a p value less than 0.05 was considered significant. The data are presented in tables and boxplots (showing the median and IQR).

Results

During the study period, twenty residents who had little, or no laparoscopic experience, were subdivided into two groups:

➢ Group A: Ten residents began their training on a pelvic trainer, were assessed using a checklist, then were trained on a VR simulator and were assessed using electronic autoassessment via the simulator.
➢ Group B: Ten residents began their training on the VR simulator and were assessed via electronic autoassessment by the simulator (test 2), then were trained on a pelvic trainer and assessed using a checklist.

Table 1 shows that the mean score on the peg transfer task for the pelvic trainer was the highest, while that on the running stitches task for the pelvic trainer was the lowest. Additionally, the mean scores for the cutting pattern and running stitches tasks were the highest for the VR simulator, while those for peg transfer were the lowest for the VR simulator (Figs. 13 and 14).

Table 2 shows that the mean score on the cutting pattern and peg transfer tasks by the pelvic trainer was greater in group A than in group B, but the difference was not significant. Table 3 shows that the mean scores for the cutting pattern, running stitches, and peg transfer tasks in group A determined by the VR simulator were greater than those in group B, but the difference was not significant (Figs. 15,16, 17, 18, 19, 20, 21 and 22).

Table 1 Descriptive statistics of scores of pelvic trainer and simulator of all trainers

		Mean	Standard deviation	Median	Percentile 25	Percentile 75
Pelvic trainer	**Camera navigation**	80	11	80	70	85
	Cutting pattern	82	11	80	73	90
	Running stitches	78	13	77	70	90
	Peg transfer	85	9	85	80	90
VR Simulator	**Camera navigation**	89	6	90	84	94
	Cutting pattern	92	6	95	86	96
	Running stitches	92	8	95	84	97
	Peg transfer	88	5	89	86	92

The test scores are described as a percentage

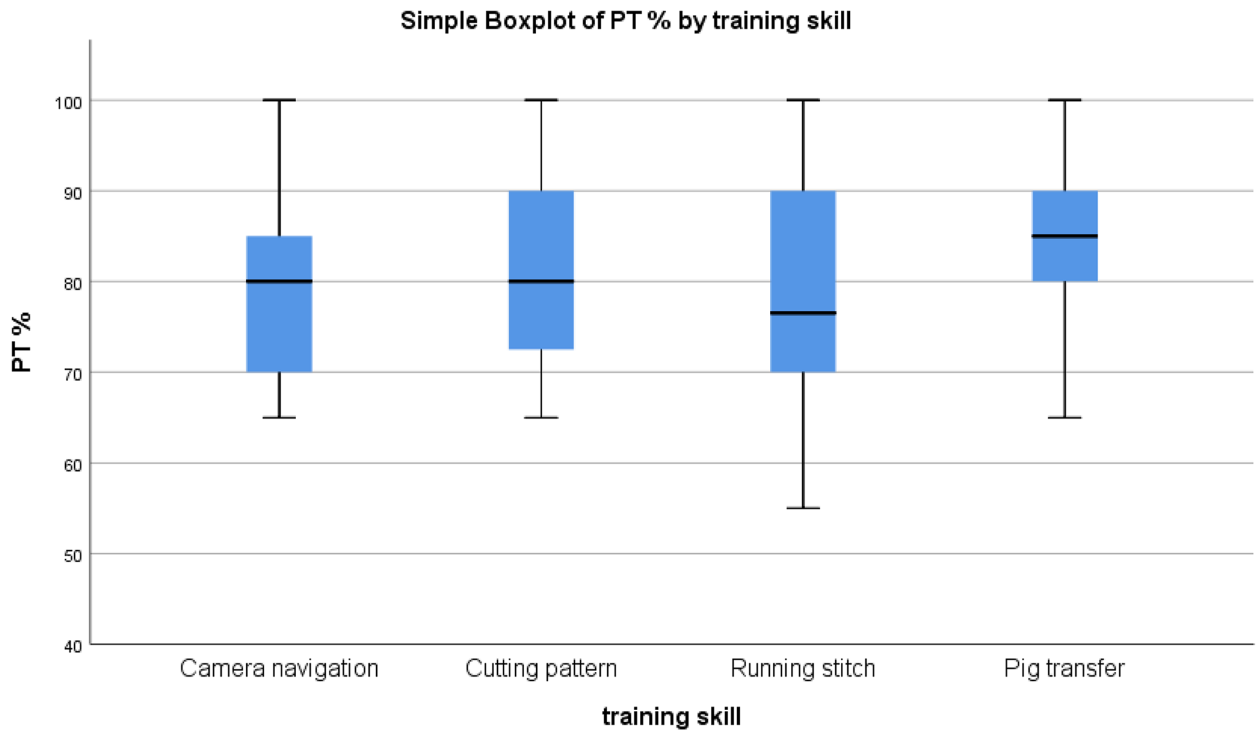

Fig. 13 Pelvic trainer skills. Simple boxplot of the pelvic trainer skills median and IQR percent

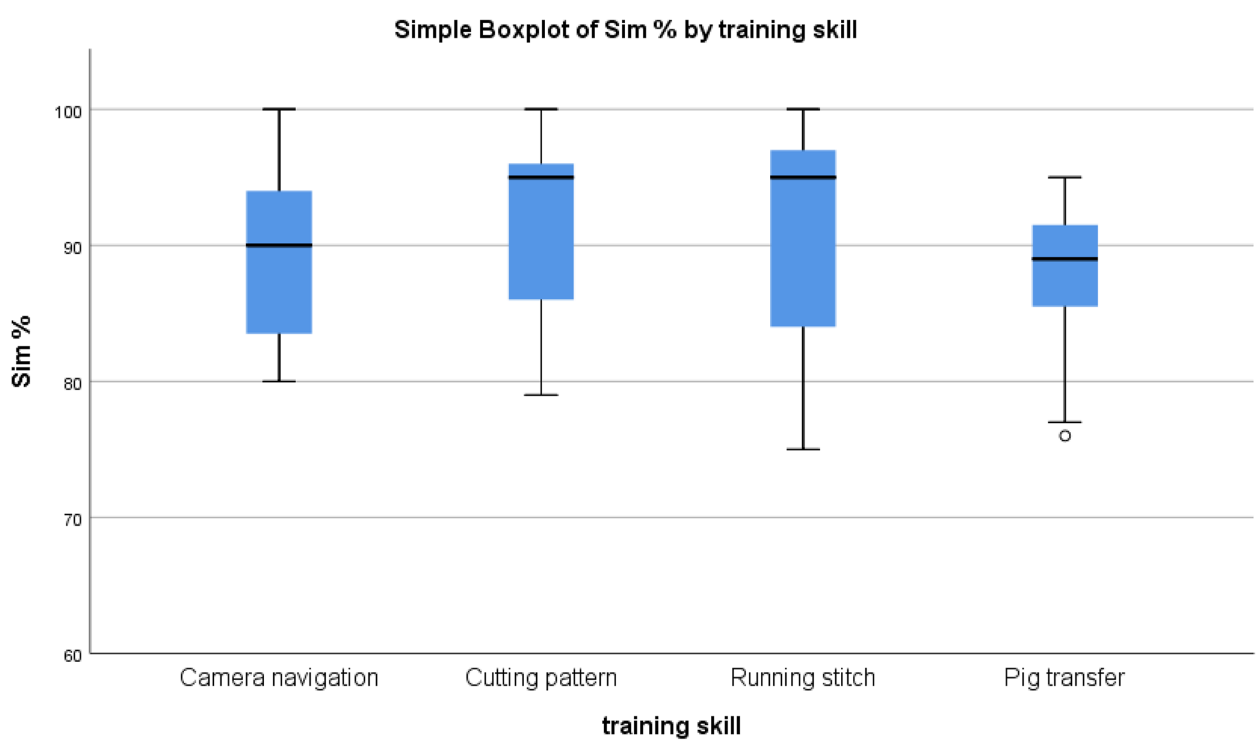

Fig. 14 LapSims skills. Simple boxplot of the LapSims skills median and IQR percent

Table 2 Comparison of pelvic trainer skills between the 2 trained groups

Group	Group A ($n=10$)			Group B ($n=10$)			*p* value
Training skill	**Mean**	**Standard deviation**	**Median**	**Mean**	**Standard deviation**	**Median**	
Camera navigation	80	13	73	80	9	80	0.646
Cutting pattern	84	12	83	80	10	78	0.341
Running stitches	78	14	78	78	13	77	0.939
Peg transfer	88	7	88	82	10	83	0.179

Table 3 Comparison of simulator skills between the 2 trained groups

Group	Group A ($n=10$)			Group B ($n=10$)			*p* value
Training skill	**Mean**	**Standard deviation**	**Median**	**Mean**	**Standard deviation**	**Median**	
Camera navigation sim	89	7	90	89	6	90	0.79
Cutting pattern sim	94	5	96	91	7	94	0.30
Running stitches sim	95	6	97	88	8	89	0.06
Peg transfer sim	90	4	90	87	6	89	0.33

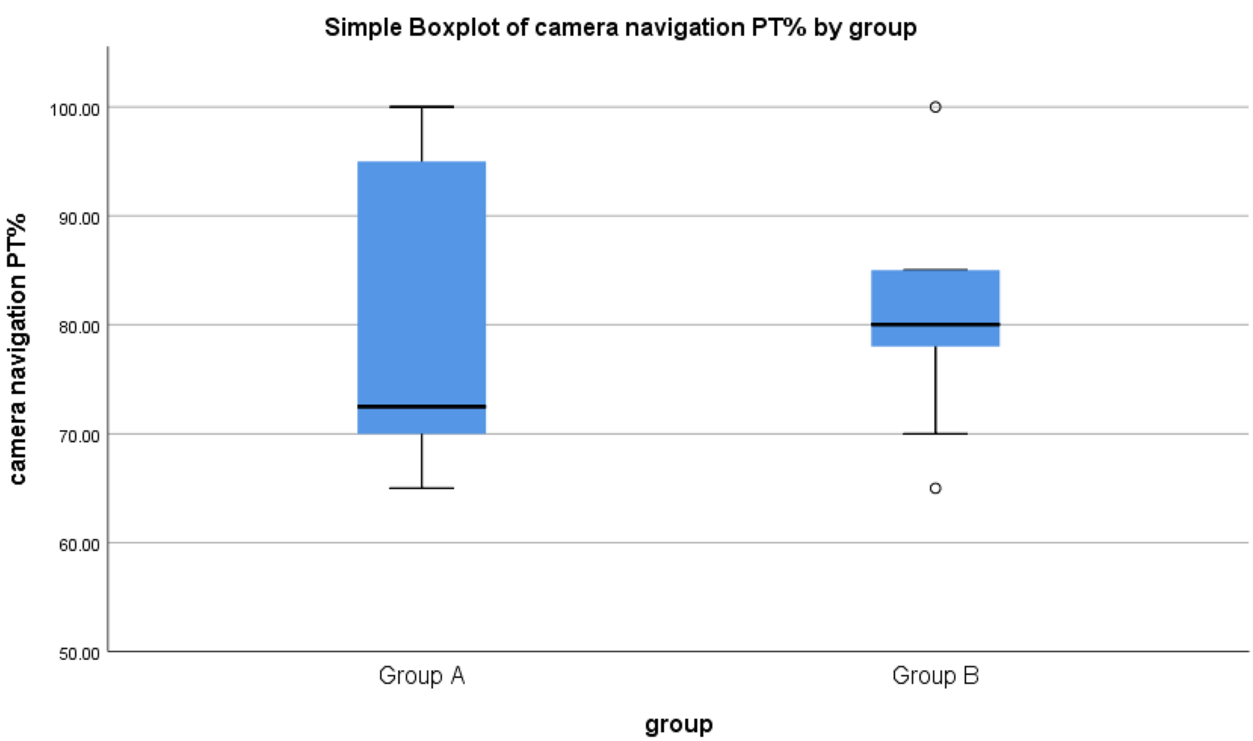

Fig. 15 Camera navigation task by the pelvic trainer. Simple boxplot of camera navigation task by the pelvic trainer between the two trained groups

Discussion

In the last 20 years, minimally invasive surgery has come to be standard practice for treating gynecologic disorders due to its broad acceptance. Considerable evidence suggests that laparoscopic surgery has significant benefits over open surgery due to the lack of

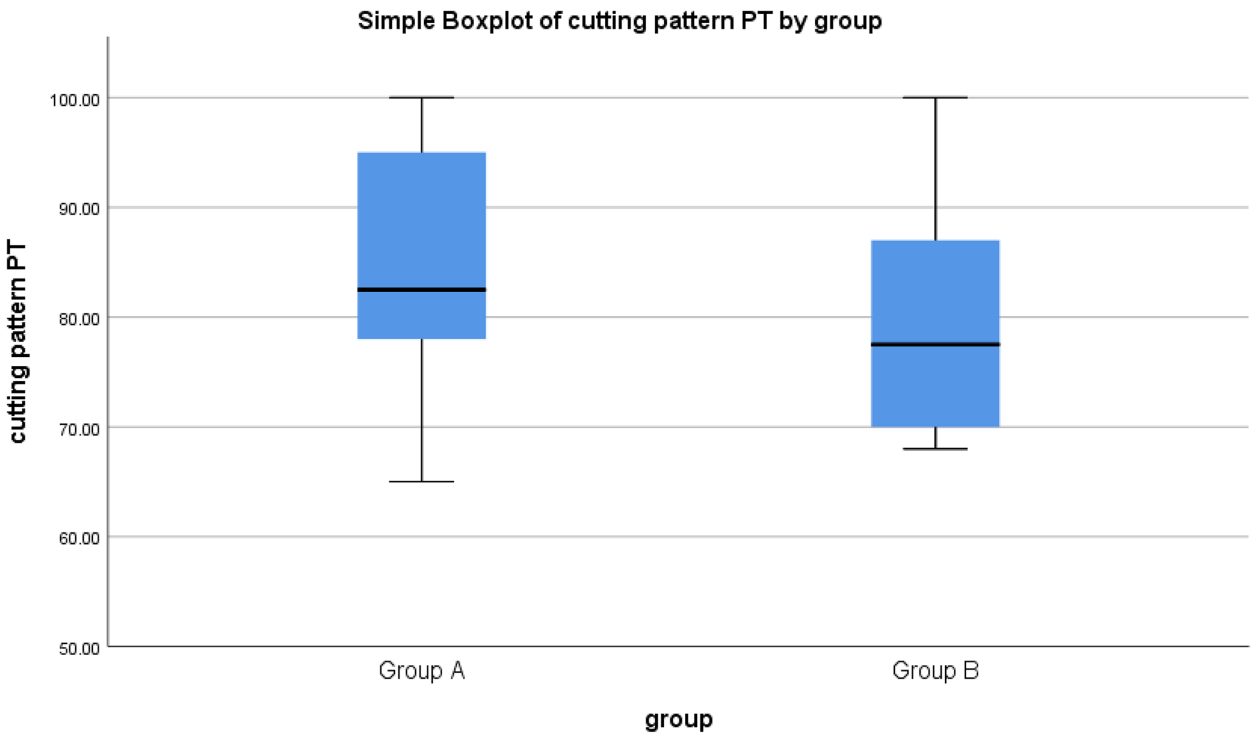

Fig. 16 Cutting pattern by the pelvic trainer. Simple boxplot of cutting pattern task by the pelvic trainer between the two trained groups

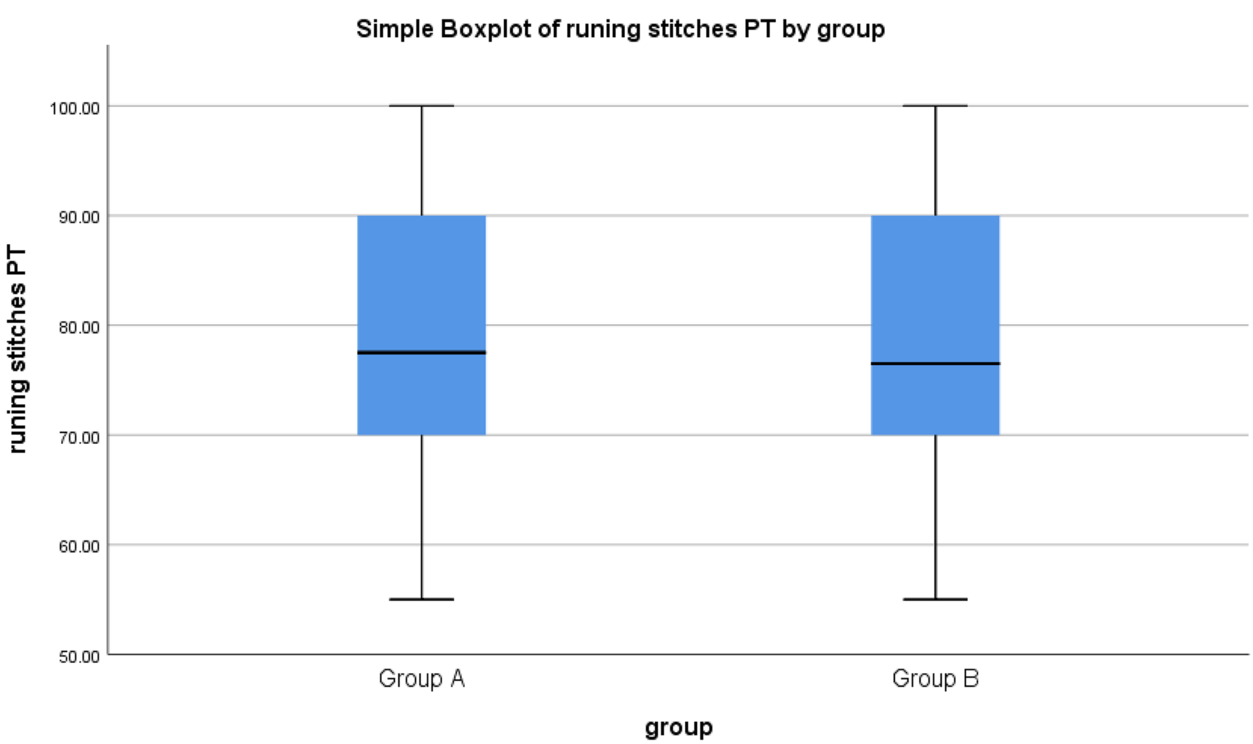

Fig. 17 Running stitches task by the pelvic trainer. Simple boxplot of running stitches task by the pelvic trainer between the two trained groups

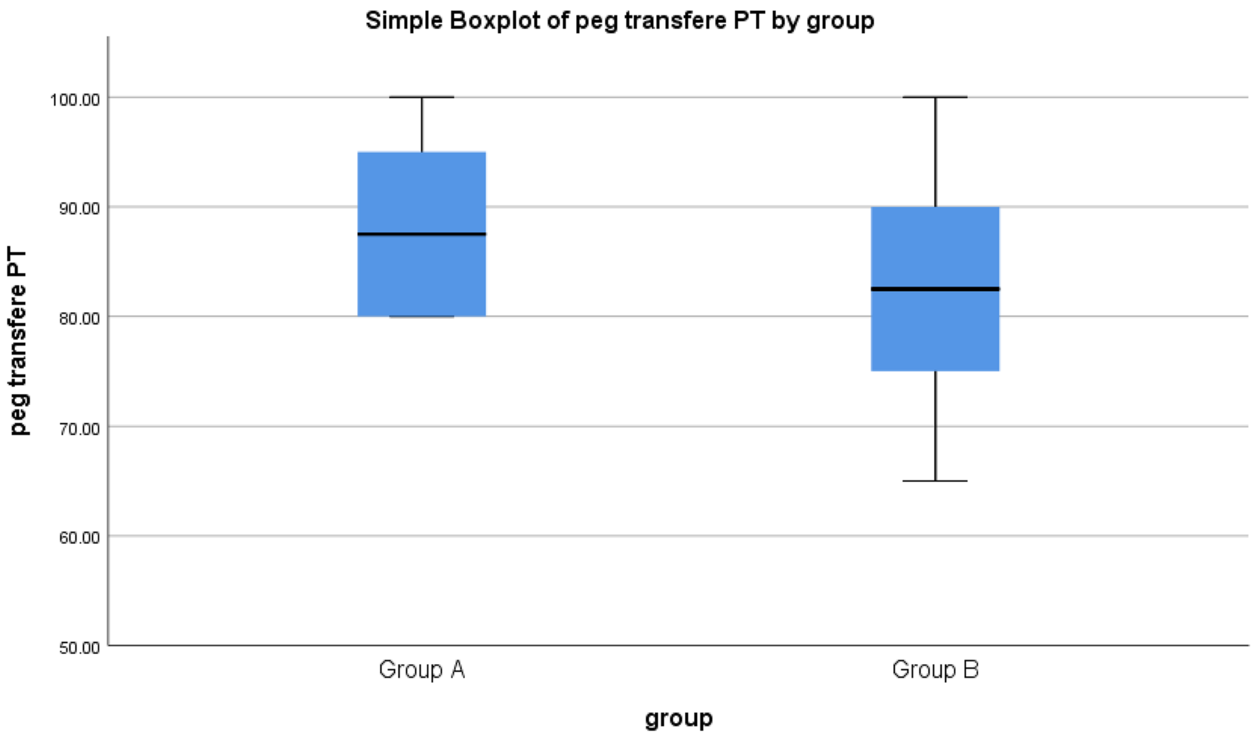

Fig. 18 Peg transfer task by the pelvic trainer. Simple boxplot of peg transfer skill by the pelvic trainer between the two trained groups

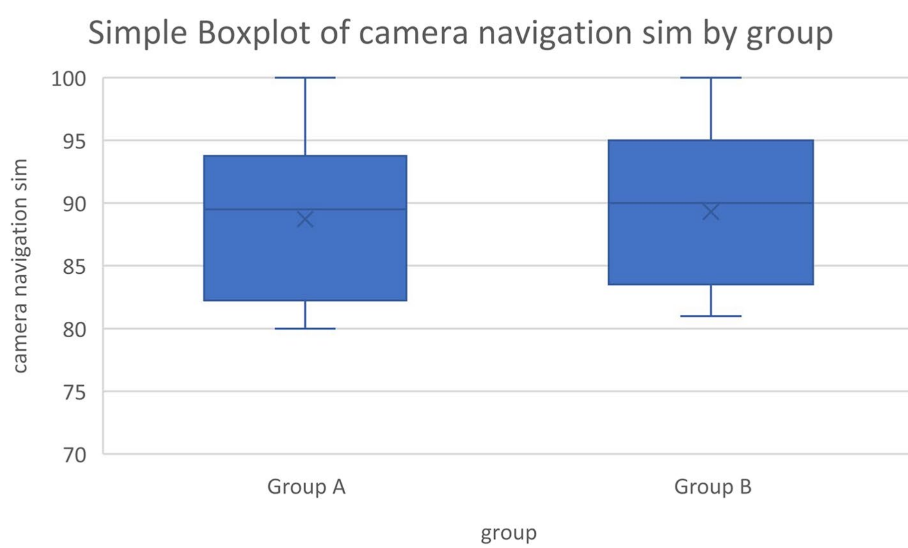

Fig. 19 Camera navigation task by the LapSims. Simple boxplot of camera navigation task by the LapSims between the two trained groups

a large abdominal incision. These benefits include little postoperative pain, shortened hospital stays, faster postoperative recovery, better cosmetic results, fewer wound-related complications, and lower costs. Recent data suggest that up to 80% of gynecologic surgeries can be accomplished laparoscopically [4].

Over the last 10 years, there has been a significant increase in the usage of laparoscopic simulators and simulation-based surgical teaching. The two primary training technologies utilized in hospitals and clinical training institutes to enhance laparoscopic surgery abilities are box trainers (BTs) and virtual reality (VR) simulators.

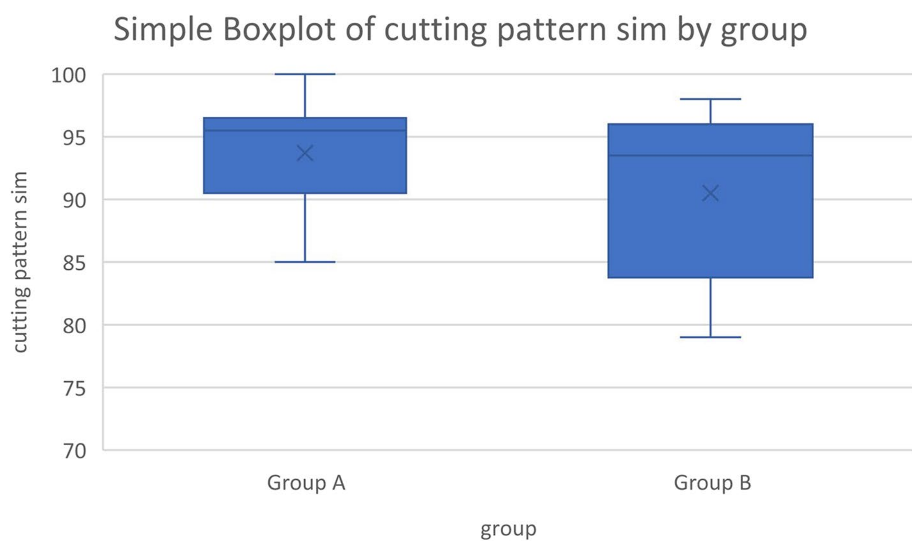

Fig. 20 Cutting pattern task by the LapSims. It shows a simple boxplot of cutting pattern task by the LapSims between the two trained groups

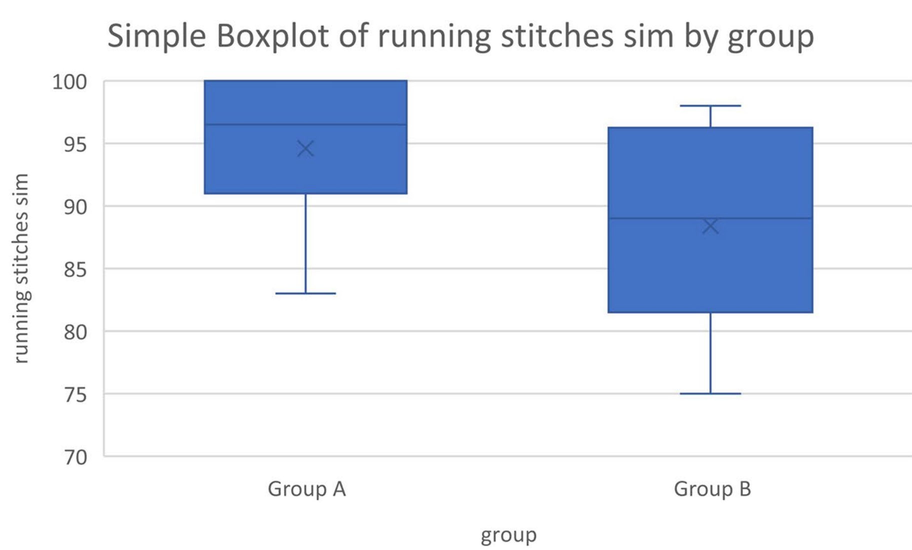

Fig. 21 Running stitches task by the LapSims. Simple boxplot of running stitches task by the LapSims between the two trained groups

However, VR simulators and BTs have several fundamental limitations; for example, VR simulators do not show depth as well as BTs do, and sometimes, the pictures in VR are not as realistic for certain tasks. However, BTs do not have a way to automatically measure performance, whereas training models require replacement after task performance and maintenance [5].

Virtual reality applications in healthcare are driven by several objectives, which include reducing the rate of error in patient care, increasing virtual training opportunities to supplement reductions in clinical practice time, specifically limited access to training inside operating rooms (ORs), and providing safer, controlled environments to facilitate training without compromising patient safety. In surgery, the use of VR facilitates the practice of basic and complex procedures both in the field and through simulated training in laboratory environments [6].

It has been shown that surgical residents who receive delicate simulator training improve their technical skills in the operating room, resulting in fewer mistakes and injuries, an increased capacity to attend to the cognitive aspects of surgical expertise, more efficient movement during the procedure, and a notable reduction in operating time [7].

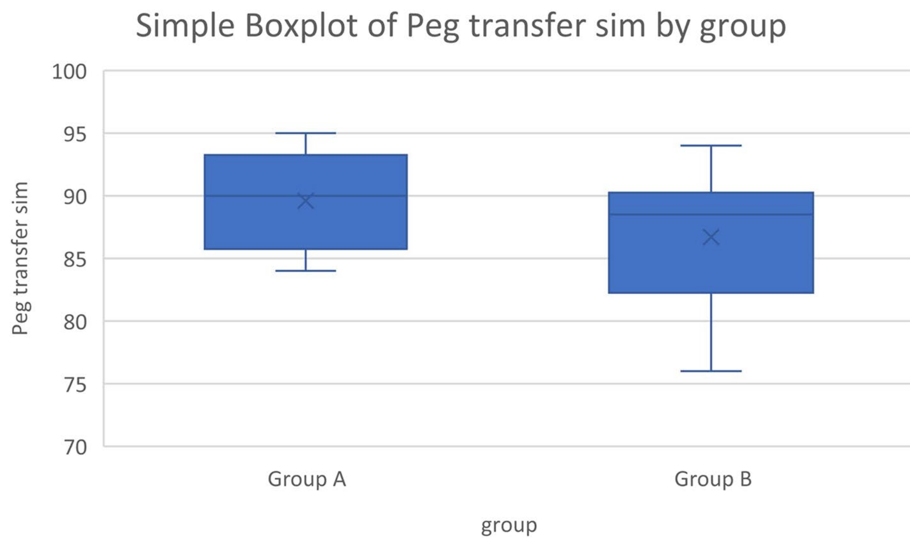

Fig. 22 Peg transfer task by the LapSims. Simple boxplot of peg transfer task by the LapSims between the two trained groups

In our study, we evaluated the proper sequence of pelvic trainers and VR simulator training to improve laparoscopic gynecological skills. We found no difference in whether the training started on a pelvic trainer or the VR simulator.

Many other studies have been conducted to assess the use of box trainers and laparoscopic VR simulators for proper laparoscopic training.

In 2008, Tanoue and colleagues conducted research to determine which method—using a virtual reality simulator or a laparoscopic box trainer—was more effective for teaching trainees endoscopic surgery abilities. They discovered that when training different skills, laparoscopic VR and box trainers both performed better than controls and produced varied results [8]. Laparoscopic box trainers and laparoscopic VR simulators were found to be equally efficient in teaching laparoscopic skills by Diesen et al. (2011) [9]. Conversely, testing using a low-fidelity FLS box trainer seems to show more validity than testing using a high-fidelity Lapsim virtual reality laparoscopic simulator, according to Hennessey and Hewett [10].

Torricelli et al. suggested that the best way to disseminate laparoscopic surgery to obstetric-gynecology residents is through the use of laparoscopic simulators for a short training period [11].

At a teaching hospital affiliated with a university, a randomized controlled trial was carried out to compare the effects of trainee-directed virtual reality simulation training and box training on the acquisition of laparoscopic suturing skills. Participants lacking prior laparoscopic suturing experience were recruited to receive suturing skill training in the virtual reality simulator, box training, or no training as a control. Thirty-six participants were recruited. Twenty-seven participants (75%) had no laparoscopic experience. Training completion times were longer for those without prior laparoscopic expertise than for those with experience (median 90 [interquartile range (IQR) 80–115] vs 55 min [IQR 40–65]; $p = 0.044$). Comparing the box trainer and virtual reality simulator to participants who had no training, they found that neither one improved the time or performance score. These results stand in contrast to numerous earlier studies that provided compelling proof that frequent, concentrated laparoscopic training on high- and low-fidelity trainers enhances laparoscopic competency in both surgery and simulation [12]. However, we should take into consideration that in vitro training is not a substitute for supervised laparoscopic surgical training on actual patients but rather simply an initiation step to familiarize interested physicians with basic laparoscopic techniques.

Papanikolaou et al. proposed that to improve patient care while maintaining safety, efficiency, and cost-effectiveness, teaching hospitals implement training programs utilizing laparoscopic simulators with standardized and repeatable tasks [13].

A limitation of our study was the small sample size, lack of power calculations, and inability to assess the competence of the participants; therefore, we cannot assume that they have become competent at laparoscopic surgery and can perform procedures safely on real patients.

In conclusion, there was no difference in training, whether started on a pelvic trainer or on the VR simulator; therefore, both could be used in laparoscopic training with no preferred order.

Abbreviations

BTs Box trainers
FLS Fundamentals of laparoscopic surgery
VR Virtual reality

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Not applicable.

Authors' contributions
Conception and design of the study: AEM and AA. Data collection: NYS and MA. Data analysis and interpretation: MA. Statistical analysis: MA.Manuscript preparation: MA. Recruitment of patients: NYS.The authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author as a supplementary file.

Declarations

Ethics approval and consent to participate
Ethical approval is attached as a supplementary material document. The study protocol was approved by the institutional review board (code: MS-182–2021) in November 2020, and written informed consent was obtained from all residents before inclusion in the study.

Consent for publication
All residents provided informed written consent that the study results would be published.

Competing interests
The authors declare no competing interests.

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