Enhancing Surgical Skills through Telesimulation: A Multicenter Randomized Controlled Trial on Laparoscopic Inguinal Hernia Repair

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Abstract

Background:

Telesimulation has been shown to be effective for teaching simple surgical techniques; however, its usefulness for teaching advanced skills remains unclear. The aim of this randomized controlled trial was to investigate the impact of a telesimulation program on training for laparoscopic inguinal hernia repair.

Methods:

Novice trainees were randomly assigned to the intervention group (IG) or control group (CG) using a permuted block design. IG participants received a one-hour didactic telelecture and three one-hour telesimulation sessions with a hernia specialist, while CG participants engaged in self-directed training using the same simulator and materials. Trainees' procedural videos, recorded before and after training, were assessed using the transabdominal preperitoneal (TAPP) Checklist and the Global Operative Assessment of Laparoscopic Skills-Groin Hernia (GOALS-GH). Pre- and post-training tests were performed to evaluate knowledge of inguinal hernias and self-confidence in TAPP procedures.

Results:

Forty-three participants from 16 institutions in Japan were enrolled, with 22 and 19 in the IG and CG, respectively, completing the final analysis. Median post-test TAPP checklist scores were 16 (IQR: 15-18.5) in the IG and 11 (IQR: 8.5-14.5) in the CG; IG participants significantly outperformed their counterparts ($p<0.001$). However, comparison of pre- and post-test scores showed skill improvements in both groups ($p<0.001$). Both groups also showed increased knowledge and confidence.

Conclusions:

The telesimulation program effectively enhanced the surgical skills of novice trainees in learning laparoscopic inguinal hernia repair, demonstrating superiority over self-directed learning.

Keywords: telesimulation; laparoscopic inguinal hernia repair; Transabdominal Preperitoneal (TAPP); surgical education

Introduction

In the 1990s, the advent of laparoscopic procedures necessitated surgeons to acquire new skills, resulting in an increase in complications. Consequently, simulation has become a crucial component of surgical residency training[1]. Numerous studies have indicated that simulator training can enhance surgical skills in both simulated environments and operating rooms[2, 3]. Recently, telesimulation has gained popularity as a means for learners to receive remote training from instructors using the internet[4, 5], eliminating limitations such as distance, time, and the need to congregate at simulation centers. The recent coronavirus disease 2019 (COVID-19) pandemic has further accelerated the shift towards online education and training, as social distancing measures have made onsite training difficult. Consequently, telesimulation training has become increasingly prevalent in the field of surgical education[6, 7].

Several reports have highlighted the efficacy of telesimulation in teaching surgical skills. Okrainec et al.[8] demonstrated the effectiveness of telesimulation in teaching the Fundamentals of Laparoscopic Surgery (FLS) with a proctor in Canada and trainees in Botswana. Mizota et al.[9] developed a coaching method for laparoscopic intracorporeal suturing using a telesimulation system. Moreover, a recent study exhibited that advanced laparoscopic suturing skills improved with telesimulation in both the operating room and a simulation setting[10]. However, the effectiveness of telesimulation training in advanced surgical procedures has not yet been conclusively demonstrated.

In a previous study, we developed a telesimulation curriculum that encompasses an online didactic lecture and skill training for transabdominal preperitoneal (TAPP) repair[11]. Novice surgeons can acquire knowledge about inguinal hernia and learn to perform the procedure using laparoscopic inguinal hernia repair (LIHR) simulators. The previous study only examined the feasibility of telesimulation training curriculum of the TAPP procedure for novice trainees[11]. We hypothesized that a telesimulation training curriculum, combined with real-time feedback during skill training and personalized one-on-one lectures, would facilitate greater improvement in both knowledge and skills for participants, even for advanced procedures, compared to those who underwent self-directed training. The objective of this multicenter randomized controlled trial (RCT) is to investigate the educational effects of a telesimulation curriculum with an instructor on the skill acquisition process for the TAPP procedure.

Methods

Ethical issues

The study was approved by the Institutional Review Board (IRB) of the Faculty of Medicine at Hokkaido University (IRB No. Med 20-037), and individual IRB approvals were obtained from the participating facilities. The participants were apprised of the study's objectives and provided written consent. All personal information was protected.

Trial Registration

This study was registered as "The study about usefulness of a telesimulation curriculum for laparoscopic inguinal hernia repair" in the University hospital Medical Information Network (www.umin.ac.jp: UMIN000043733).

Study design

This multicenter, RCT was conducted in compliance with the CONSORT statement (Figure 1) using a two-group parallel design with 1:1 assignment. Multiple institutes around Japan with interest in surgical education and hernia were contacted and participants were recruited from the interested institutes. Eligible participants had experience with no more than one TAPP procedure and were required to perform intracorporeal suturing based on the FLS within 112 s as a criterion for mastering basic laparoscopic surgical techniques[12].

Prior to the intervention, the participants underwent a baseline assessment of their knowledge of inguinal hernia and TAPP procedures using a previously developed 15-point didactic test[11]. Their baseline skills were assessed in the simulator, and they were required to complete a questionnaire regarding their confidence in performing TAPP procedures. Video recordings of the simulation performance were evaluated using the TAPP checklist[13]. Participants who scored more than 16 on the baseline skill assessment were excluded from the study.

All the participants were provided with an LIHR simulator, five sets of peritoneum models, one camcorder, one set of 2 LapaSta® (a portable port for dry box training secured by suction cups), one Palm camera stand® (a camcorder fixing device), platforms connected to Palm camera stand® to hold a smartphone, one acrylic board showing the placement of objects, laparoscopic scissors, two laparoscopic forceps, one laparoscopic Maryland grasper, one laparoscopic needle holder, one tacker, some sheath of mesh, and suture materials by post. Participants were required to set up a simulator based on the instruction videos.

After the baseline test, the surgical trainees were randomly assigned to either the intervention group (IG) or the control group (CG). After three weeks, all participants completed the previously developed didactic test and TAPP procedure skills test in simulator settings.

Intervention group

Participants allocated to the IG initially underwent a one-hour didactic telelecture regarding inguinal hernia, utilizing the previously developed didactic material[11]. Subsequently, they underwent three one-hour telesimulation training sessions, which were conducted once a week over three weeks by a single instructor who trained all the participants. The instructor had experience in more than 200 TAPP procedures and was certified as a master of endoscopic surgery under the Endoscopic Surgical Skill Qualification System of the Japan Society of Endoscopic Surgery[14]. Training was provided with the same simulator setup as that previously described in our study (Figure 2)[11]. The setup for the trainee used a commercially available inguinal hernia sheet (Fasotec Co. Ltd., Chiba, Japan), which allowed dissection between its layers. This sheet was attached to a commercially available inguinal hernia base (Fasotec Co. Ltd., Chiba, Japan). In the instructor's simulator setup, a stocking was used as the peritoneum and mounted on the same inguinal hernia base. As reported earlier, the cost of the perishable items used in one training session was 94 US dollars [11]. In the first session, the instructor demonstrated the procedure one step at a time on their simulator, verbally explaining each step. The trainee then replicated the demonstrated step on their own simulator. The instructor observed the trainee's performance and provided verbal cues if they encountered difficulties. If the trainee was still unable to complete the step, the instructor paused the trainee and demonstrated the step again on their simulator. This process continued, with the instructor demonstrating each subsequent step after the trainee completed the previous one, until the procedure was completed. Starting from the second session, the trainee performed the procedure from the beginning, with the instructor offering verbal guidance as needed. If the trainee encountered difficulty despite the cues, the instructor paused them and demonstrated the step again on their simulator. The instructor did not use an assessment tool to evaluate performance; instead, they offered technical advice regarding ways to approach each step of the procedure. Each session concluded with summative feedback from the instructor, who explained what the trainee did well and what needed improvement. The inguinal hernia base used in this study could be reused multiple times without structural damage. The inguinal hernia sheet could be stored in its packaging and reused for about one week. Participants were encouraged to practice unsupervised between training sessions in their free time, using these sheets to work on various aspects of groin hernia repair.

Control group

To accurately reflect the conditions experienced by the trainees during the study, those in the CG underwent self-directed training for three weeks using the same simulator settings and didactic materials as those used by the IG. Following the post-test, the participants were given the option of TAPP telesimulation training by the instructor and received feedback on their technique.

Skill assessment

In this study, trainees' performance in the simulator was evaluated using two previously validated assessment tools for LIHR: the TAPP Checklist and the Global Operative Assessment of Laparoscopic Skills-Groin Hernia (GOALS-GH)[15, 16]. The TAPP checklist includes 18 procedure-specific items and 6 generic items[15]. Two procedure-specific items related to port insertion, one generic item on use of the energy device and another generic item related to bleeding could not be evaluated using the simulator and were excluded. Each item was assigned 1 point if the trainee fulfilled the criteria in the assessment tool and 0 points if the trainee did not fulfill the criteria. The minimum score was 0 and maximum score was 20. GOALS-GH is a global assessment scale comprising five items[16]. Each item is scored on a 5-point Likert-type scale from 1 to 5, mainly assessing the knowledge and surgical technique required in that step. The item related to trocar placement was excluded in this study. The trainee could receive a minimum score of 4 and a maximum score of 20 on this scale. A trained, blinded video rater reviewed video recordings of the trainees' performances. The operation time was standardized to one hour based on the duration of the surgeons with varying experience levels in the simulator.

Rater

The rater in this study was a board-certified general surgeon with experience in laparoscopic groin hernia repair. The rater underwent training in the TAPP checklist and GOALS-GH by using these assessment tool and simulation videos from expert raters who had previously developed and had extensive experience in using both these tools. Both the expert raters were board-certified minimally invasive gastrointestinal surgeons with extensive experience in LIHR. The rater independently assessed six randomly selected simulator videos with the expert rater. Inter-rater reliability between the new and expert raters was then calculated. Once the inter-rater reliability was confirmed, the remaining videos were evaluated by the new rater. All videos were randomized and blinded before the assessment.

Outcomes

The primary outcome of this study was the improvement in TAPP checklist scores according to blinded video assessments after three weeks of training. Secondary outcomes included the GOALS-GH score and improvement in participants' knowledge of inguinal hernia using a previously developed test with a maximum score of 15[11]. The study also aimed to assess changes in the participants' confidence levels using a questionnaire consisting of seven items related to each step of the TAPP repair procedure, which included a peritoneal incision to create a peritoneal flap, dissection of the preperitoneal layer, reduction of the hernia sac, adequate dissection of the preperitoneal space, mesh introduction, positioning and fixation, peritoneal suturing, and the overall procedure flow, rated on a scale of 1–10. After training, the trainees completed a questionnaire on the usefulness of the TAPP telesimulation training for surgical education on a scale of 1–5. Furthermore, we investigated the amount of time the participants spent in each group devoted to self-practice and telesimulation training over three weeks.

Sample size

In the pilot study[11], we collected data from three novices during a single training session. In this session, the trainees' skills improved from a TAPP checklist pretest score of 2.8±1.8 to 10.0±4.0. We hypothesized that after three training sessions, the trainees in the IG would improve their scores to 16.0±4.0, while those in the CG would improve to 12.0. To detect a significant difference between the two groups with an alpha level of 0.05 and a power of 0.8, we calculated that a sample size of 16 participants per group was required. Considering potential dropouts, we aimed to recruit a minimum total of 40 participants for the study.

Randomization

Participants were allocated to either the IG or the CG through permuted block randomization, performed using a web-based randomization service (https://www.sealedenvelope.com). The researcher who performed the randomization was blinded to the participants' identities and stratified the allocation by facility, postgraduate year, and assessment scores of both the baseline test and skill assessments.

Statistical analysis

The Mann–Whitney U test was used to evaluate differences in continuous data between the two groups, while the chi-square test was used to assess differences in categorical data. The Wilcoxon signed-rank sum test determined the score improvements before and after training in each group. Inter-rater reliability was assessed using intraclass coefficients. Data are presented as median (interquartile range). Statistical significance was set at a two-tailed $P<0.05$. All analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, New York, USA).

Results

A total of 43 individuals from 16 Japanese institutions were included in this study between March 2021 and January 2022 (Supplementary Table 1). The trial concluded upon reaching the target number of participants. Two CG participants withdrew from the study due to their failure to complete the training and evaluation. Ultimately, the post-test was completed by 22 individuals in the IG and 19 individuals in the CG, who were included in the final analysis (Figure 1). Participant characteristics are presented in Table 1.

The intraclass correlation between two raters for six videos was excellent at 0.95 (0.69–0.99) for the TAPP checklist and 0.96 (0.73–0.99) for GOALS-GH. Consequently, the remaining videos were assessed blindly by only one rater.

Pretest TAPP checklist scores were comparable between the two groups; however, the median post-test scores were significantly higher in the IG (16; IQR: 15–18.5) than in the CG (11; IQR: 8.5–14.5; $p < 0.001$) (Table 2). However, compared to the pretest performance, the post-test performance was significantly improved in both groups (both TAPP checklist and GOALS-GH: IG $P < 0.001$, CG $P < 0.001$) (Table 2).

There was no statistically significant difference in the pretest scores on the knowledge test between the trainees of both groups (*P*=0.45). Both groups demonstrated a significant improvement in their knowledge scores on the post-test (CG; *P*=0.02, IG; *P*<0.01), and there was no significant difference between the post-test scores of the two groups (*P*=0.43) (Table 2).

Following training, the participants' median confidence scores in various aspects of the TAPP procedure improved significantly in both groups. A significant difference was observed between the CG and IG, especially with respect to the creation of the dissection space and mesh deployment (Table 2). IG participants agreed that the TAPP telesimulation curriculum was valuable for assessing and training the TAPP procedures. There was no significant difference in the time spent on self-practice between the IG and CG (*P*=0.28) participants (Table 1).

Discussion

This investigation highlights the significant enhancement in the technical abilities of beginner trainees through telesimulation, even in advanced procedures such as TAPP. Equipping trainees with simulators and training materials proved to be sufficient to improve their skills. Nonetheless, having an instructor resulted in supplementary improvement in their abilities and reduced variation among the trainees.

Telesimulation facilitates the education and training of learners in remote locations, thereby eliminating geographical and temporal barriers and inconveniences[4]. The benefits of telesimulation training are anticipated to expand further in the future, as learners can receive instruction from instructors regardless of their location and gain access to a diverse array of educational resources. In this investigation, we imparted a telesimulation training curriculum to novices across Japan, including those situated at a considerable distance of 3,000 km. With regard to simulation training, all 41 participants engaged in the training irrespective of their physical proximity. As for the IG, despite the need to coordinate their schedules with the instructor, they were able to receive feedback and guidance from the instructor, resulting in effective skill enhancement, even though the training was conducted remotely. While competency-based training is generally favored in simulation training, this study demonstrated that three telesimulation training sessions significantly improved novice skills. In a pilot study, novices exhibited improvements in their TAPP skill scores, even after a single training session[11]. Therefore, for this training, three sessions were employed, taking into account cost considerations and realistic feasibility factors, such as scheduling instructors and participants. Despite the TAPP telesimulation curriculum consisting of only three sessions, the novices could score 80% of the maximum score. However, the goal of the simulation training should be to train the trainees until they can consistently attain the maximum score. To achieve this, our study shows that they would need more training with instructors or a competency-based approach. Upon comparing the IG and CG, it was observed that confidence levels improved even with simulator training alone. However, the ability to create a dissection space and mesh deployment while receiving instructor guidance further augmented confidence, and the feedback provided by the instructor was deemed impactful.

Several studies have underscored the significance of feedback in acquiring and refining technical skills in surgical education[17]. Poudel et al.[18] demonstrated significant improvement in novice trainees' skills in TAPP procedures using assessment and feedback alone. Strandbygaard et al.[19] previously observed that having an instructor provide feedback after training enhances the effectiveness of simulation training in virtual reality simulators. More recently, Tejos et al.[20] showed that receiving feedback from either a peer or an expert surpasses video-based simulation for simple laparoscopic suturing.

Our investigation also affirmed the efficacy of telesimulation for training in advanced procedures.

During our study, the instructor was present during the training session and provided concurrent feedback to the trainees. Additionally, the trainees received summative feedback at the end of the session. A meta-analysis concluded that terminal feedback was more effective than concurrent feedback in skill training for novice trainees[21]. Recent studies have also highlighted the value of using web-based tools to provide trainees with asynchronous feedback during simulations[22, 23]. However, it should be noted that most of these studies involved simple techniques, such as suturing or a part of a procedure, and not the procedure as a whole. Given the complexity of the procedure, we believe that combining concurrent feedback with summative feedback was more efficient in helping the trainees in our study improve their skills and contributed to minimizing the skill gap between the trainees.

The instructor's impact on improving the knowledge of participants in our study was not observed as a significant additive effect. Research has shown that interactive learning is essential for gaining knowledge[24]. Although the lectures were conducted in a one-to-one format, allowing ample opportunities for the trainees to interact with the lecturer, this alone did not significantly enhance their knowledge. To improve the didactic content of the telesimulation curriculum, it may be necessary to redesign it using an interactive, multidirectional, and learner-centered approach. It may also be beneficial to hold interactive discussions with multiple trainees during lectures.

This study has several limitations. Because the study was conducted during the COVID-19 pandemic, we only evaluated trainees' skills in a simulated setting, and transferability to the operating room was not demonstrated. Previous research has demonstrated that the simulator used in this study has been effective in improving LIHR skill both in a simulated setting and in the operating theater[2]; therefore, we expect that the LIHR skill of trainees in actual surgery will also improve. Although telesimulation training is not a competency-based program due to resource limitations in terms of human resources and time, approximately 70% of the participants in the IG achieved the predetermined competency goal. This shows that the TAPP telesimulation training curriculum had an excellent educational effect, even within a limited training time.

Conclusion

Our study demonstrated the effectiveness of a TAPP telesimulation curriculum supplemented with concurrent feedback from an instructor in enhancing the surgical abilities of novice trainees. This TAPP telesimulation training curriculum has the potential to be employed for training surgical residents who are newly embarking on laparoscopic surgery, not only within Japan but also on a global scale in the future.

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Disclosures

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Table 1. Background characteristics of the participants

	Control group (n=19)	Intervention group (n=22)	p value
Postgraduate year (2/3/4)	8/8/3	12/8/2	0.68
Number of trainees with experience in TAPP as an operator	0	1	0.35
Experience in TAPP as an assistant	3 (1.0-10.0)	2 (0-9.8)	0.17
Experience in other laparoscopic procedures as an operator	2 (0-10.0)	2 (1.0-9.5)	0.54
Self-practice time during the study (min)	460 (283-593)	320 (243-578)	0.28
Total duration of telesimulation training (min)		187 (182-193)	

Categorical data are presented as number of participants; while continuous data are presented as median (interquartile range).

Table 2. Improvements in various scores

	Control group (n=19)	Intervention group (n=22)	p value
TAPP Checklist score			
Pretest score [20]	4.0 (2.0-6.0)	5.0 (3.0-6.8)	0.29
Post-test score [20]	11.0 (8.5-14.5)	16.0 (15.0-18.5)	**<0.01***
p value	**<0.01***	**<0.01***	
GOALS GH score			
Pretest score [20]	4.0 (4.0-4.0)	4.0 (4.0-5.0)	0.48
Post-test score [20]	8.0 (7.5-13.5)	15.0 (13.0-17.0)	**<0.01***
p value	**<0.01***	**<0.01***	
Knowledge test scores			
Pretest score [15]	8.0 (6.5-9.0)	7.0 (5.3-8.0)	0.45
Post-test score [15]	9.0 (8.5-11.0)	10.0 (8.0-11.0)	0.43
p value	**0.02***	**<0.01***	
Self-confidence scores			
Peritoneal incision [10]			
Pretraining	1.0 (1.0-4.0)	2.0 (1.0-3.0)	0.43
Post-training	5.0 (4.0-6.0)	6.0 (5.0-6.8)	0.43
p value	**<0.01***	**<0.01***	
Creation of dissection space [10]			
Pretraining	1.0 (1.0-3.0)	1.0 (1.0-2.0)	0.68
Post-training	5.0 (3.5-5.0)	6.0 (5.0-7.0)	**0.01***
p value	**<0.01***	**<0.01***	
Reduction of hernia sac [10]			
Pretraining	1.0 (1.0-2.5)	1.0 (1.0-2.0)	0.31
Post-training	4.0 (2.5-5.0)	4.0 (3.3-5.0)	0.99
p value	**<0.01***	**<0.01***	
Extent of dissection [10]			
Pretraining	1.0 (1.0-2.0)	1.0 (1.0-2.0)	0.71
Post-training	5.0 (3.5-6.0)	5.0 (4.3-6.8)	0.54
p value	**<0.01***	**<0.01***	
Mesh deployment [10]			
Pretraining	1.0 (1.0-2.0)	1.0 (1.0-2.0)	0.75
Post-training	5.0 (4.0-7.8)	6.0 (4.0-7.8)	**0.01***

p value	**<0.01***	**<0.01***	
Peritoneum closure [10]			
Pretraining	1.0 (1.0-3.0)	2.0 (1.0-3.8)	0.33
Post-training	5.0 (3.5-7.0)	5.0 (4.0-7.0)	0.71
p value	**<0.01***	**<0.01***	
Overall procedure [10]			
Pretraining	1.0 (1.0-2.0)	1.0 (1.0-2.0)	0.71
Post-training	4.0 (3.0-5.5)	5.0 (4.3-6.0)	0.33
p value	**<0.01***	**<0.01***	
The questionnaire scores: TAPP telesimulation training is [5]			
Usefulness for assessing surgical skills	4.0 (4.0-5.0)	4.0 (4.0-5.0)	0.83
Usefulness for training in surgical skills	4.0 (4.0-5.0)	5.0 (4.0-5.0)	1.00

Data are presented as median (interquartile range).

The maximum attainable score for each section is indicated in brackets [ ]. The p-values in the columns compare the scores between the control group and the intervention group. Meanwhile, the p-values in the rows represent the difference in scores before and after the training. Statistically significant differences are highlighted with an asterisk (*) and bold text.

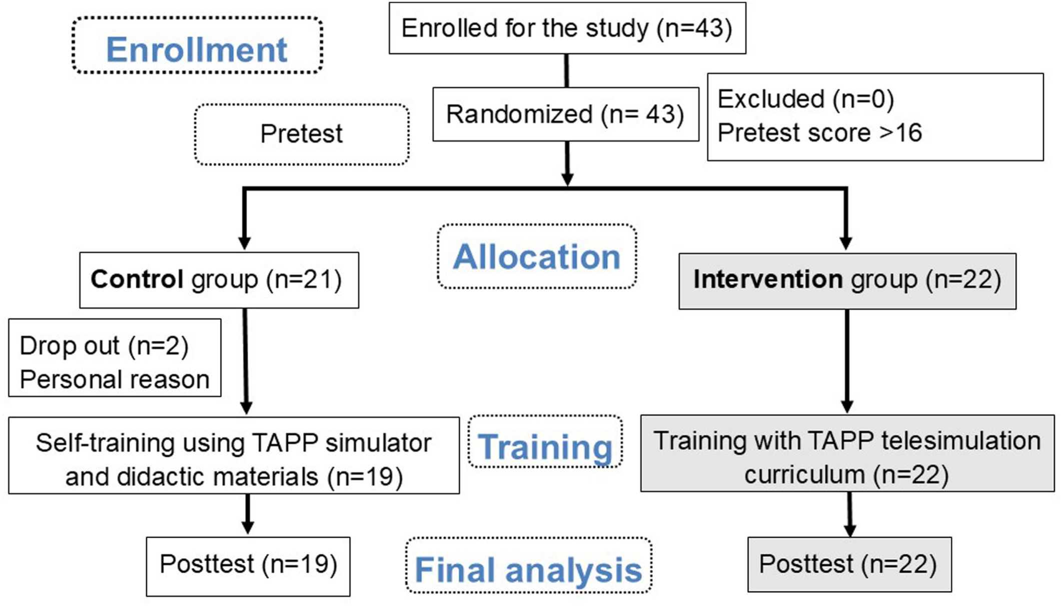
TAPP: transabdominal preperitoneal

GOALS-GH, Global Operative Assessment of Laparoscopic Skills-Groin Hernia

Figure 1. The CONSORT Diagram.

Figure 2. Set up for TAPP telesimulation training system.

The previously known laparoscopic inguinal hernia repair simulator was (11) connected to the monitor via camcorder. The trainees performed the TAPP procedure with telecommunicating the instructor using their smartphones via Zoom.


Enrollment
Enrolled for the study (n=43)
Pretest
Randomized (n= 43)
Excluded (n=0)
Pretest score >16
Allocation
Control group (n=21)
Intervention group (n=22)
Drop out (n=2)
Personal reason
Self-training using TAPP simulator and didactic materials (n=19)
Training
Training with TAPP telesimulation curriculum (n=22)
Posttest (n=19)
Final analysis
Posttest (n=22)


TOSHIBA