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Comparison of 2D versus 3D in the Basic Single Incision Laparoscopy Training. A Randomized Controlled Trial

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Rezumat

Compararea antrenamentului 2D față de cel 3D în tehnica laparoscopiei printr-un singur port: un studiu randomizat controlat

Context: Chirurgia laparoscopică printr-o singură incizie este o procedură dificilă din punct de vedere tehnic. Utilizarea laparoscopiei 3D poate îmbunătăți rezultatele instruirii în procedurile laparoscopice printr-un singur port. Scopul acestui studiu a fost de a compara efectele pe termen scurt pe care le are utilizarea laparoscopiei 3D față de cea 2D asupra instruirii chirurgilor în procedurile printr-un singur port.

Metode: Patruzeci de chirurgi (25 de bărbați şi 15 de femei) fără experiență anterioară în chirurgia laparoscopică cu o singură incizie au participat la studiu. Participanții au fost împărțiți aleator într-un grup care a utilizat modul 2D şi un grup care a utilizat modul 3D.

Rezultate: Douăzeci de participanți au fost repartizați în grupul de instruire 2D şi douăzeci în grupul de instruire 3D. Timpul pentru a finaliza prima sarcină ce a constat în transferul mingii din polipropilenă, a fost semnificativ mai scurt în grupul 3D, fără nicio diferență în numărul total de erori de pe parcursul exercițiului (p=0,007). Numărul total de încercări şi numărul de încercări reuşite au fost similare între grupuri, în timp ce numărul de erori a fost semnificativ mai mare în grupul 2D în timpul exercițiului de apucare a acului (p=0,033). În testul de legare a nodurilor intracorporale, probabilitatea de a finaliza sarcina a fost semnificativ mai mare în grupul 3D (p=0,02).

Concluzie: Antrenamentul 3D în tehnicile de bază de laparoscopie pe o singură incizie pare să ofere avantaje față de modul standard de antrenament 2D.

Cuvinte cheie: laparoscopie 3D, chirurgie laparoscopică cu o singură incizie, SIES, pregătire chirurgicală, chirurgie minim invazivă

Abstract

Background: Single incision laparoscopic surgery is a technically challenging procedure. The use of 3D laparoscopy can potentially improve training results. The aim of the present study was to compare the short-term effects of the 2D vs 3D single incision laparoscopy training.

Methods: Forty novices (25 males and 15 females) with no prior experience in single incision laparoscopic surgery participated in the study. The participants were randomized into 2D or 3D training mode.

Results: Twenty participants were assigned to 2D and twenty to 3D training group. Time to finish the first task with the polypropylene ball transfer was significantly shorter in the 3D group with no difference in the total number of errors during the task (p=0.007). Overall number of attempts and number of successful attempts were similar between the groups while the number of errors was significantly higher in the 2D group during the needle grasping task (p=0.033). In the intracorporeal knot tying test the probability of completing the task was significantly higher in the 3D group (p=0.02).

Conclusion: 3D training in basic single incision laparoscopy techniques seems to offer advantage over standard 2D training mode.

Key words: 3D laparoscopy, single incision laparoscopic surgery, SIES, surgical training, minimally invasive surgery

Introduction

Single Incision Laparoscopic Surgery (SIES) is a technically challenging branch of minimally invasive surgery. One if its limitation in performing complex tasks includes intracorporeal suturing in a standard 2D laparoscopy vision. Current advances in the laparoscopic equipment can result in a wider acceptance of SIES approach.

Almost all surgical procedures can be performed using SIES technique, including hernia repair (1), bariatric surgery (2), and Nissen fundoplication (3).

When compared to the multiport procedures, the limitation of the 2D laparoscopic techniques such as lack of stereoscopic vision and depth perception, in SIES procedures can affect surgical performance and physical and mental comfort of the operating surgeon even further (4).

On the other hand, the 2018 European Association of Endoscopic Surgery (EAES) consensus for the use of 3D laparoscopic systems suggested that the introduction of 3D technology could potentially improve laparoscopic box trainer task completion time and lower the error rate. The introduction of the 3D laparoscopy shortens the operative time across all analyzed surgical specialties, also suggesting a lowering in the overall rate of complications after surgical procedures involving suturing in 3D laparoscopy (5).

A recent study conducted by So Hyun Kang et al. showed the shortened operative time during single incision distal gastrectomy using 3D camera compared to 2D mode with possible clinical benefits for patients (6).

The aim of the study was to compare the short-term effects of the 2D vs 3D approach in SIES training.

Materials and Methods

The study was conducted at the Minimally Invasive Surgery department of the Center

for Innovative Medical Technology of the National Academy of Sciences of Ukraine. Period of recruitment was from June 2020 till December 2020.

Forty novices (male, n= 25; female, n= 15) with no prior experience in SIES laparoscopic surgery nor in laparoscopic surgery as operating surgeon participated in the study.

Among the participants there were 3 medical university students, 34 residents in surgery and 3 post graduate researchers.

Informed consent was collected prior to the study from all participants.

All participants were shown 3D video of the surgical procedure and declared clear vision of the image in 3D.

Exclusion criteria were: involvement in any SIES procedure, former laparoscopic box training with SIES port, systematic training with multiport laparoscopic box of more than 10 hours per month, fellowship/training program in MIS surgery during the last 6 months, epilepsy, eye conditions which did not allow to look at the monitor for a long time, seasickness.

To evaluate the participants' level of expertise all participants were asked to fulfil the questionnaire prior to the participation in the study. The complete characteristics of the study groups are presented in *Table 1.*

Randomization

We used simple randomization with paper cards. The result of the randomization was attached to the participant's name badge. The randomization process is presented in *Fig. 1.*

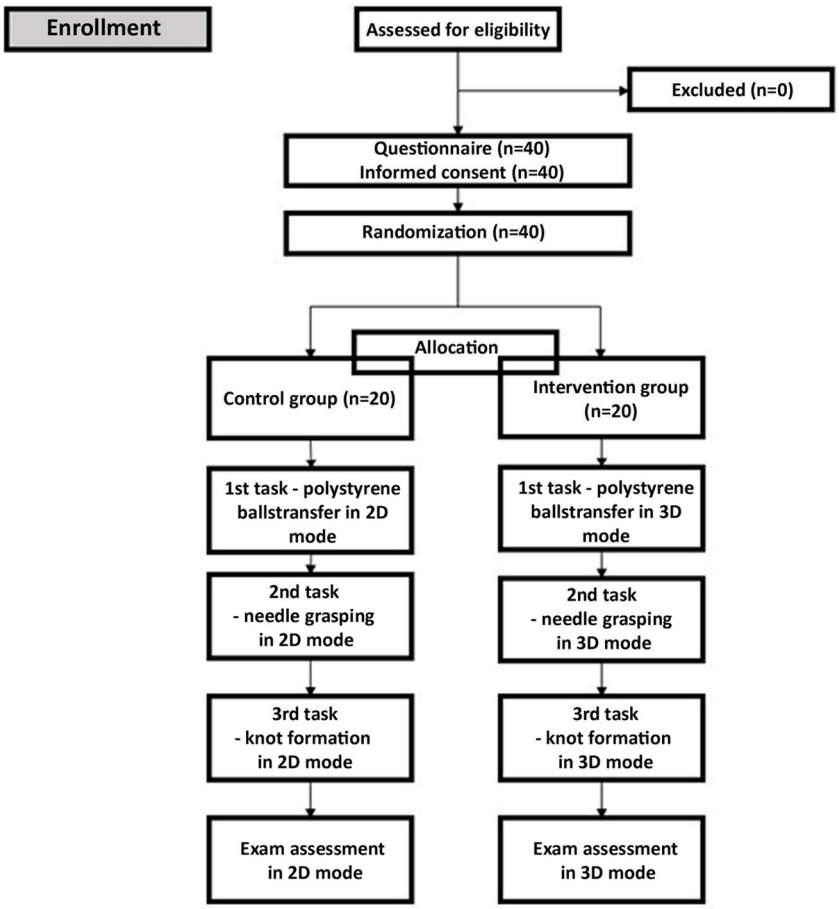

Figure 1. CONSORT diagram. The training was completed in 2D and 3D mode

Table 1. Participants' characteristics

Parameter		Group		p
		2D group (N=20)	3D group (N=20)	
Age (years)	mean±SD	24.55±2.78	24.55±1.73	p=1
	median	25	24	
	quartiles	23 - 26	24 - 25	
Hours of sleep	mean±SD	6.72±1.02	6.53±0.98	p=0.501
	median	7	6.5	
	quartiles	5.88 - 7.5	6 - 7	
Sex	Female	9 (45%)	6 (30%)	p=0.514
	Male	11 (55%)	14 (70%)	
Dominant hand	Left	1 (5%)	1 (5%)	p=1
	Right	19 (95%)	19 (95%)	
Year of residence/PG	Uni. student: 3. year	1 (5%)	0 (0%)	p=0.241
	Uni. student: 5. year	1 (5%)	0 (0%)	
	Uni. student: 6. year	0 (0%)	1 (5%)	
	Residence: 1. year	9 (45%)	7 (35%)	
	Residence: 2. year	3 (15%)	9 (45%)	
	Residence: 3. year	4 (20%)	2 (10%)	
	PG: 2. year	1 (5%)	1 (5%)	
	Unknown	1 (5%)	0 (0%)	
Previous experience: Assistance	Never	6 (30%)	4 (20%)	p=0.733
	1-10 times	6 (30%)	6 (30%)	
	More than 10 times	8 (40%)	10 (50%)	
Previous experience: Training box	0 hours/months	12 (60%)	12 (60%)	p=1
	1-10 hours/months	8 (40%)	7 (35%)	
	More than 10 hours/months	0 (0%)	0 (0%)	
	Unknown	0 (0%)	1 (5%)	
Mobile Gaming	Rare	7 (35%)	9 (45%)	p=0.74
	Intermediate	7 (35%)	6 (30%)	
	Often	2 (10%)	4 (20%)	
	Unknown	4 (20%)	1 (5%)	
PC Gaming	Rare	12 (60%)	10 (50%)	p=0.565
	Intermediate	3 (15%)	6 (30%)	
	Often	2 (10%)	3 (15%)	
	Unknown	3 (15%)	1 (5%)	
Console Gaming	Rare	12 (60%)	11 (55%)	p=0.478
	Intermediate	2 (10%)	6 (30%)	
	Often	1 (5%)	2 (10%)	
	Unknown	5 (25%)	1 (5%)	
Music	Rare	5 (25%)	8 (40%)	p=0.814
	Intermediate	5 (25%)	5 (25%)	
	Often	4 (20%)	4 (20%)	
	Unknown	6 (30%)	3 (15%)	
Painting	Rare	10 (50%)	12 (60%)	p=0.879
	Intermediate	3 (15%)	2 (10%)	
	Often	3 (15%)	3 (15%)	
	Unknown	4 (20%)	3 (15%)	
Knitting	Rare	10 (50%)	13 (65%)	p=0.292
	Intermediate	3 (15%)	0 (0%)	
	Often	2 (10%)	1 (5%)	
	Unknown	5 (25%)	6 (30%)	
Watching surgical videos: YouTube	Rare	3 (15%)	2 (10%)	p=0.451
	Intermediate	7 (35%)	12 (60%)	
	Often	9 (45%)	6 (30%)	
	Unknown	1 (5%)	0 (0%)	
Watching surgical videos: Professional platforms	Rare	6 (30%)	3 (15%)	p=0.351
	Intermediate	6 (30%)	10 (50%)	
	Often	6 (30%)	4 (20%)	
	Unknown	2 (10%)	3 (15%)	
Sport activity: Professional	Rare	7 (35%)	8 (40%)	p=1
	Intermediate	2 (10%)	1 (5%)	
	Often	1 (5%)	2 (10%)	
	Unknown	10 (50%)	9 (45%)	
Sport activity: Amateur	Rare	5 (25%)	4 (20%)	p=0.907
	Intermediate	7 (35%)	9 (45%)	
	Often	4 (20%)	5 (25%)	
	Unknown	4 (20%)	2 (10%)	

p - Mann-Whitney test for quantitative variables, chi-squared or Fisher's exact test for qualitative variables

Development of the Training Box for the SIES

As the base for the training box, a simple plastic storage box (49x31x14 cm) was chosen. Inside the box, borders for the inserts positioning were marked with a permanent marker. GelPOINT Advanced Access Platform from Applied Medical with three 10 mm low profile sleeves, positioned in a regular manner and instrument shield were attached to the Plexiglas holder using Alexis Wound Retractor, mimicking a 3 cm wound. The plexiglass holder was attached to the box in a manner to achieve 45°instrument axis angle for the tasks (*Fig. 2*) (7).

Before handson training, every participant in a group of two had an individual lecture containing 27 slides with the focus on the basics of SIES approach, with the possibility of the pretraining experience with the different devices for the SIES approach (SILS Port, GelPOINT Advanced Access Platform, S-Port by Storz), instrument design, and ergonomics.

Training Tasks

The training session, which was divided into three tasks – ball transfer, intracorporeal stich, and intracorporeal knot tying, was scheduled for 15 minutes each. Before each assignment, the mentor explained for 5 minutes to the participant possible options for the training tasks completion, what errors might occur, and how to avoid them.

Figure 2. Overview of the training box

All tasks were previously evaluated by the group of surgeons with proficiency in MIS and SIES surgery.

1st task – polystyrene ball transfer.

Polystyrene balls are a cheap substitute to the regular pegs used for a laparoscopic training and have some discrete advantages. When the participant squeezes the ball with the clamp, the trace of such an action remains on the paint that covers the ball surface, which can be noted by the mentor. It should also be noted that for a comfortable transfer of the ball, it is much more important to use the rotational elements of the clamps than when transferring conventional pegs, which in turn may indicate a better control of the laparoscopic instrument. For this task, a platform with three pools was installed inside the training box. Dimensions of the platform: big right pool – 140x100x45 mm, small left bottom pool – 70x60x35 mm, small left upper pool – 70x60x35 mm.

2nd task - Needle grasping

Participants should train to grasp the needle from the surface and from the left hand. Different maneuvers were shown to the participants, including "dancing needle" and positioning on the tissue. Microporous soft fluffy synthetic sponge was used as the base for this task. Every participant received his/her own sponge to avoid damaging the surface due to the previous attempts. We found synthetic sponges low fidelity, but very cost-effective model for this task. Overview of the setup for this task is shown in the *Fig 3.*

3rd task - Knot formation

Considering overall difficulty of the SIES knot formation, the participants were given a Roticulator™ Endo Dissect with precise algorithm with clear step by step guidance for the knot formation. After the stich was completed with the straight position of the Roticulator™ Endo Dissect, its distal part was bended to the middle position using a special wheel, which provided the most efficient angle for the SIES knot tying (*Fig. 4*). Two surgical

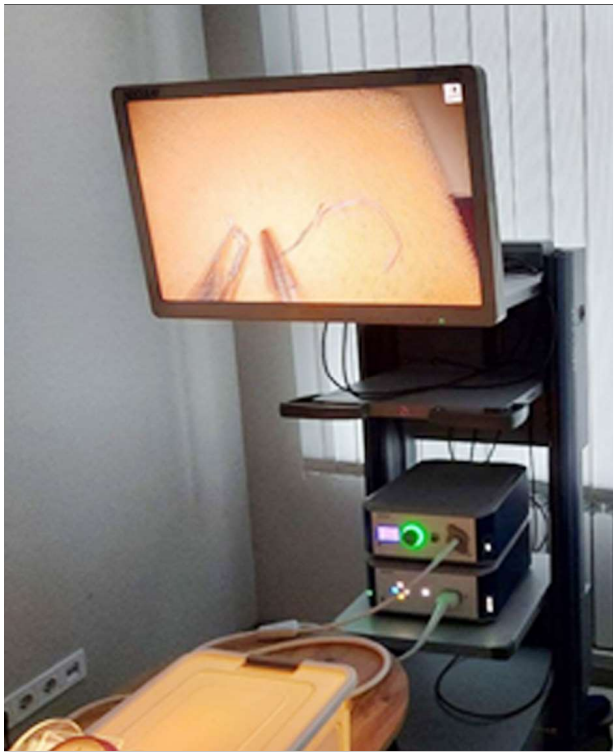

Figure 3. Needle grasping task

knots and four simple knots were performed by each participant during the training session. For the exam, we used 3 soft silicone pads attached to the polypropylene base and then mounted in the box.

Examination

The Exam was conducted in the same setting and on the same day after resting for 20 minutes. The tutor was not allowed to help participants during the tasks. Only 3 persons were allowed in the examination room at a time – the surgeon, camera assistant, and examiner. During the tasks, the data were collected in Microsoft Excel (One Microsoft Way, Redmond, Washington, U.S.) tables for further analysis. Time limit was set at 5 minutes for the first and second task and 15 minutes for the third task.

1st examination task

For this task, a platform with three pools was installed inside the training box. The essence of the assignment was as follows: in 5 minutes

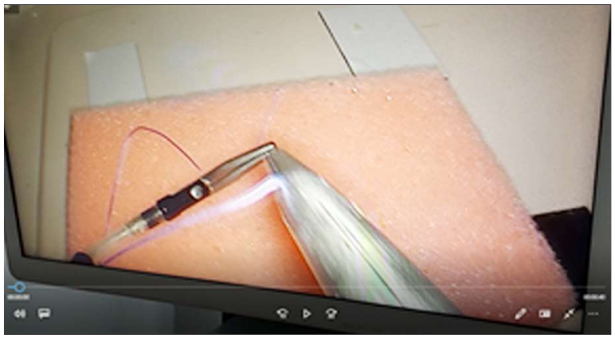

Figure 4. Position of the monocurved grasper and straight needle driver during the Knot formation task

provided for this task participants were asked to transfer 5 blue and 5 red balls from the right main pool to the left upper pool.

2nd examination task

Mentors were asked to collect the following data: overall number of attempts, number of successes, backwards moving with the needle in the needle driver, harsh moves, loss of the needle, sponge pad tear, detachment needle from the thread.

3rd examination task

For the exam, the set of three silicone pads was attached in the training box. The dimensions of each pad are shown at *Fig 5*. Task sequence was as follows: at the beginning of the exam, 150 mm monofilament polypropylene thread with the needle was attached to the right corner of the right pad for simple grasping. After needle grasping, participants passed the suture through the silicone pad, stitched the upper surface of the platform, trying not to go

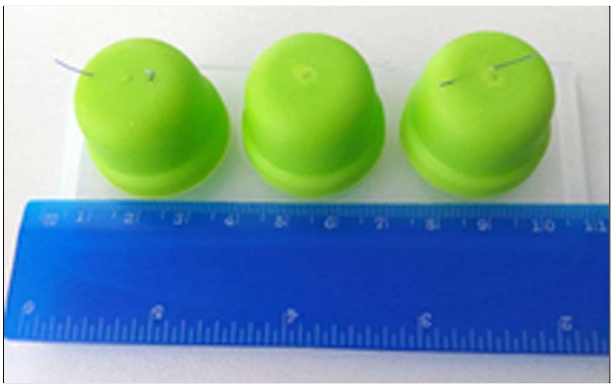

Figure 5. Silicone platforms for the stitching and knot formation

beyond it, so that the thread would not pass through the side surface of the platform. After the participant pulled the entire length of the thread through the soft material of the platform, with the help of scissors, the thread was crossed in such a way as to leave an end of no more than 5 mm.

After that, it was necessary to retake the needle using the needle holder and repeat the same task on the right platform, leaving the end of the thread of no more than 5 mm. Length of the thread which was left in the pad was extracted and measured.

The last step was formation of 1 surgical knot and at least 2 simple knots on the middle platform.

The following data were collected during the third task: completion of the task, time in seconds, numbers of knots formed, numbers of errors and description of error type– needle lost, pad detachment from the box bottom surface, marks for the pad sutures – suture in the center of the platform – 2 points, one side surface – 1 point, suture in the side wall of the pad – 0 points. All pads were collected in envelopes, marked with random generated 4 digitletter code, and length of the thread, which remained in the left and right pad, number of knots was measured by an independent person.

Equipment

All the steps of the hands-on training were performed with the EinsteinVision® 3.0 laparoscopic tower, with the Full HD resolution both in 2D and 3D mode. (Aesculap AG, Am Aesculap-Platz 78532, Tuttlingen, Germany). Aesculap PV648 32" full HD 3D monitor was mounted stationary on the cart, with the possibility to adjust the comfort level according to the height of the participants. Aesculap OP950 LED light source was used. All equipment was mounted on the standard OR Aesculap PV800 endoscopy equipment cart.

For every task, a predetermined set of instruments were proposed.

Chi-squared test (with Yates' correction for 2x2 tables) was used to compare qualitative variables among groups. In case of low values in contingency tables, Fisher's exact test was used instead.

Mann-Whitney test was used to compare quantitative variables between two groups.

Significance level for all statistical tests was set to 0.05. R 4.0.5 software was used for computations.

Forty participants were enrolled in this study. Twenty participants were assigned to 2D and twenty to 3D training group. There was no difference between the backgrounds of the two groups with regards to age, sex, hours of sleep per day, dominant hand, level of experience (year of university or residency, laparoscopy exposure, training box exposure) PC, console and mobile gaming, artistic interests, knitting, watching surgical videos, and sport activity (*Table 1*).

Task 1 (Polystyrene balls transfer)

The time to finish the first task was significantly shorter in the 3D group with no difference in the total number of errors during the task (*Table 2*, *Figs. 6, 7*).

Table 2. Results of the ball transfer task

Parameter		Group		p
		2D group (N=20)	3D group (N=20)	
Task 1: Time (s)	mean±SD	200.65±48.73	157.15±57.51	p=0.007 *
	Median	204.5	141	
	Quartiles	150 - 230.5	119.75 - 180	
Task 1: Errors	mean±SD	2.61±3.29	1.1±1.62	p=0.102
	Median	2	0.5	
	Quartiles	0 - 3.75	0 - 1.25	

p - Mann-Whitney test for quantitative variables, chi-squared or Fisher's exact test for qualitative variables
* Statistically significant (p<0.05)

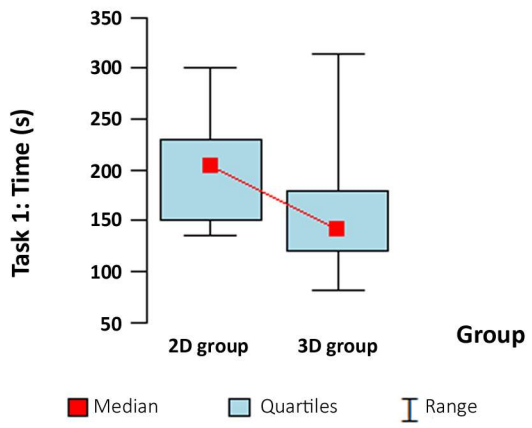

Figure 6. Time to complete the task

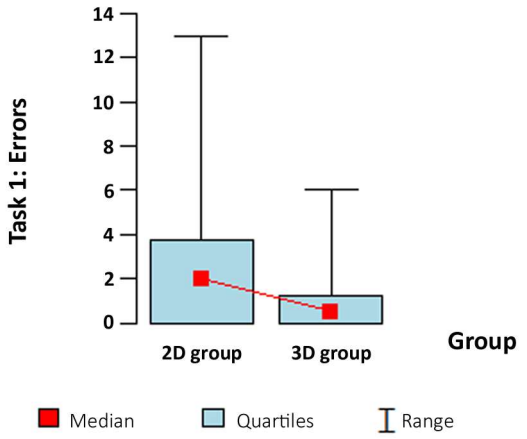

Figure 7. Errors during the ball transfer task

Task 2 (Needle grasping)

The number of attempts and that of successes were similar between the groups, while the number of errors was significantly higher in the 2D group (*Table 3, Figs. 8, 9, 10*).

Task 3 (Knot formation)

The time to finish the task was significantly longer in the 2D group. The length of the first thread was significantly longer in the 2D group. The probability of completing the task was significantly higher in the 3D group. The length of the second thread, total thread length, and the probability of successful knot formation were similar in both groups (*Table 4, Figs. 11-16*).

In one case in the 3D group result was mentioned as "unknown", which has not significant differ-ence on the result.

Discussion

While the introduction of 3D equipment in training is a well-established concept (8), combining 3D with SIES technique is rarely done in training.

With this study, we tried to establish whether it is possible to train laparoscopically naïve trainees to perform complex tasks in a short session using 3D equipment.

In the first task, the time needed for the ball transfer was significantly shorter in the 3D group, but no difference in the total

Table 3. Results of the needle grasping task

Parameter		Group		p
		2D group (N=20)	3D group (N=20)	
Task 2: Attempts	mean±SD	5.7±3.29	7.8±5.72	p=0.226
	Median	5	6.5	
	Quartiles	3.75 - 7	4 - 8.25	
Task 2: Successes	mean±SD	5.05±3.44	7.55±5.51	p=0.086
	Median	5	6	
	Quartiles	2.75 - 6	4 - 8.25	
Task 2: Errors	mean±SD	1.06±1.11	0.42±0.77	p=0.033 *
	Median	1	0	
	Quartiles	0 - 1	0 - 0.5	

p - Mann-Whitney test for quantitative variables, chi-squared or Fisher's exact test for qualitative variables
* Statistically significant (p<0.05)

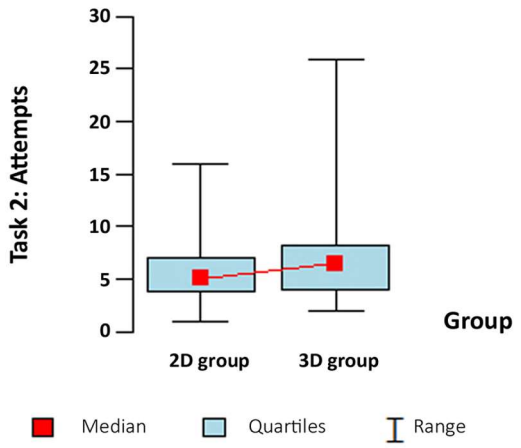

Figure 8. Needle grasping attempts

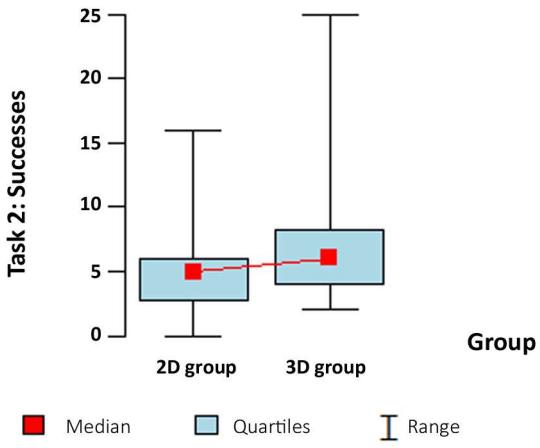

Figure 9. Needle grasping successes

number of errors during the task were noted. One participant in the 2D group did not finish the 1st task, because 1 orange and 3 blue balls were lost during the task and were not transferred to the marked boxes. Participants in the 3D group spent less time for the grasping of the ball and for the transferring, which resulted in overall time shortening in the 3D group. 3D visualization did not affect the number of errors in the balls transferring task, but showed more feeling of the depth inside the jaws of the instrument for the participants and movements were, therefore, gentler and more precise.

The number of attempts and the number of

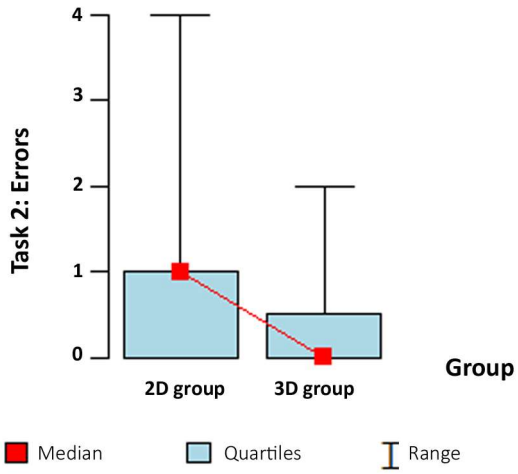

Figure 10. Needle grasping errors

Table 4. Knot formation task results

Parameter		Group		p
		2D group (N=20)	3D group (N=20)	
Task 3: Time (s)	mean±SD	876.35±74.05	772.15±128.81	p=0.002 *
	median	900	775	
	quartiles	900 - 900	688.75 - 900	
Task 3: Thread 1 length (mm)	mean±SD	27±7.01	22±6.26	p=0.028 *
	median	27.5	22.5	
	quartiles	21.75 - 30	17 - 25	
Task 3: Thread 2 length (mm)	mean±SD	23.45±7.54	22.75±8.23	p=0.424
	median	24.5	21	
	quartiles	20 - 26.5	17 - 26.25	
Task 3: Total thread length (mm)	mean±SD	50.45±9.45	44.75±13.74	p=0.113
	median	51.5	42	
	quartiles	40.75 - 56.25	36.5 - 53.5	
Task 3: Completely done	Yes	3 (15.00%)	11 (55.00%)	p=0.02 *
	No	17 (85.00%)	9 (45.00%)	
Task 3: Successful knot formation	Yes	11 (55.00%)	7 (35.00%)	p=0.415
	No	9 (45.00%)	12 (60.00%)	
	Unknown	0 (0.00%)	1 (5.00%)	

p - Mann-Whitney test for quantitative variables, chi-squared or Fisher's exact test for qualitative variables

* Statistically significant (p<0.05)

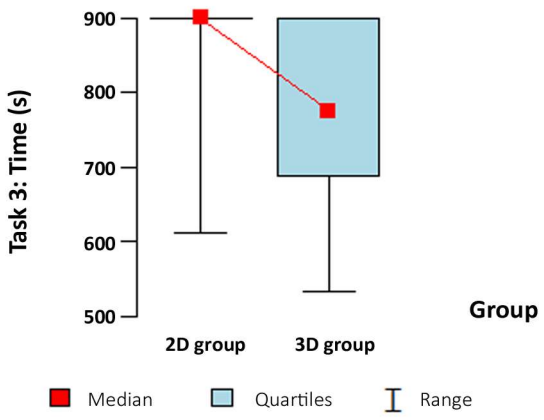

Figure 11. Time needed for the knot formation task

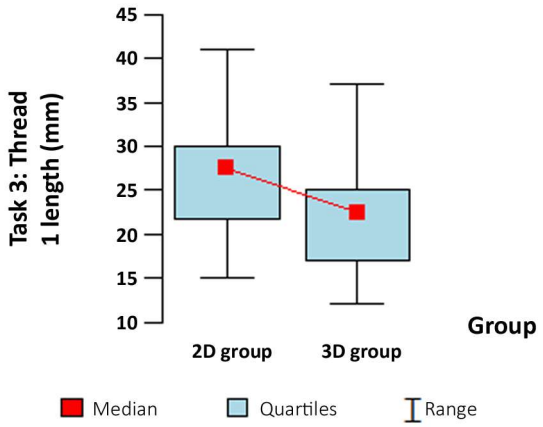

Figure 12. Length of the thread in the first pad

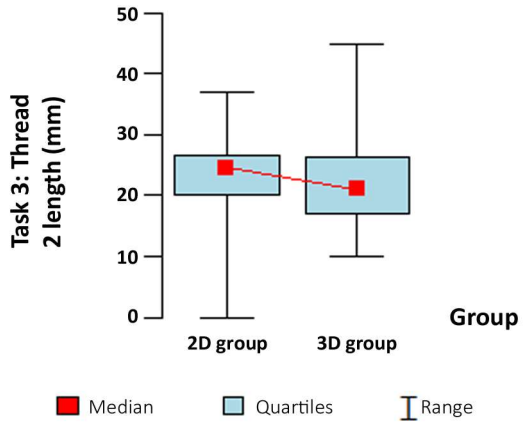

Figure 13. Length of the thread in the second pad

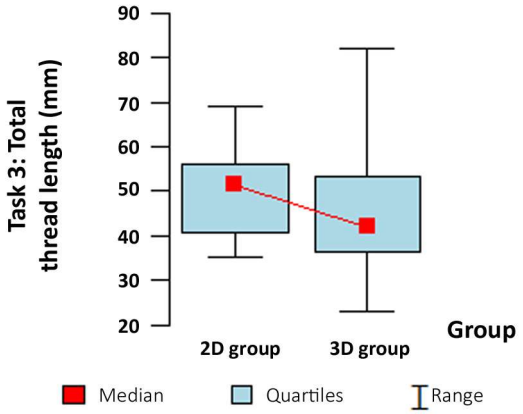

Figure 14. Total thread length

successes were similar between the groups during the needle grasping task, and the greater number of mistakes made by the participants in the 2D group can be potentially associated with the highest difficulty in clearly understanding the bound-aries of the needle and directions of its movement and perceiving it as a three-dimensional object in a 2D image.

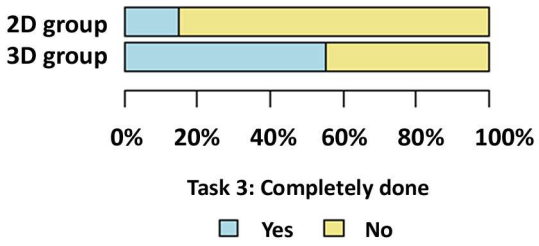

Figure 15. Ability to finish the 3d task among groups

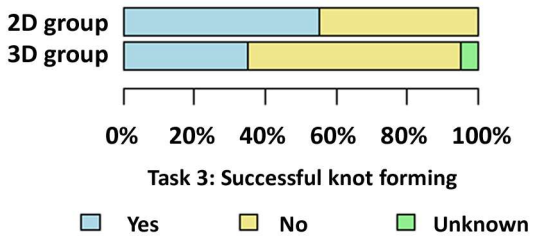

Figure 16. Success of the knot formation

It is well-established that the formation of knots and sutures is an essential requirement for advanced laparoscopic procedures and can serve as a barrier to the widespread introduction of minimally invasive surgery in a fairly wide range of surgical specialties. (9). During our training we observed that the initial experience did not affect performance much, as in the study conducted by Bansal et al., who showed that not only naïve laparoscopic surgeons can benefit from precision training, but experts increase their performance (10). One participant in the 2D group spent all the time provided for the second task in "needle hunting", trying to pick the needle and constantly losing it.

The knot formation task was among the most challenging in our study. Suturing in SIES setting is one of the most demanding technical skill. Despite that, participants in both groups, after one session of training, showed the ability to perform SIES suturing and knot formation. We used dedicated guidance list for the participants with the proper explanation of the hands position, instruments position, best beginning point and troubleshooting of the unexpected events. Partici-pants were also trained to use the open jaw of the needle holder to form a knot in situations where knotting using a dissector was not possible using the Romeo's Gladiator Rule (11).

Overall, the 3D group showed better results as 11 participants compared to only 3 in the 2D group successfully finished the task. Several participants in both groups formed the knot, but lost it after inaccurate movements. One participant in the 2D group and two participants in the 3D group performed all 3 required knots with the straight instruments, which is a more complicated task than using curved instruments suggested for the standardization of the technique. The time to finish the task was significantly longer in the 2D group, because participants spent more time for the needle grasping and applying scissors. This also leads to the longer thread tail in the 2D group, which was among other reasons of failure to complete the task in the 2D group.

Limitations of the study include the potentially low experience of the camera assistant, which can affect the results. From the other hand, all the tasks in our study have had very limited camera navigation needed and takes place almost in the same position of the box, what can neutralize this issue. Meanwhile, stationary camera holder will be not beneficiary in the task which apply timing as a score, because changing its position requires to remove the working instruments from the port. We do not have aim to show long term results of one day training, concentrated on the results of the complicated single incision task comparing the different vision modality. For the future trials longer training courses and different level of experience of the practitioners should be examined for the further conclusions (12).

In summary, the 3D training in basic laparoscopy SIES techniques for laparoscopically naïve trainees was superior to a standard 2D approach. Whether these differences can translate into long term results and better surgical technique is unclear.

Conclusion

Basic surgical training of the laparoscopically naïve trainees in single incision approach using 3D equipment was superior to a standard 2D approach.

Conflicts of Interest

All authors disclose no conflict of interests.

Source of Funding

No financial support for this study.

Compliance with Ethical Requirements

This study was approved by the ethical com-mittee of the Center for Innovative Medical Technology of the National Academy of Sciences of Ukraine, the protocol #8_15062020. Informed consent was obtained from all individual participants included in the study.

Statement of human and/or animal rights: not applicable.

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