ISSN 1392–0995, ISSN 1648–9942 (online)
http://www.chirurgija.lt
LIETUVOS CHIRURGIJA
Lithuanian Surgery
2013, 12 (4), p. 224–232

Klinikinė praktika

Training of basic laparoscopic skills in surgical education

Bazinių laparoskopinių įgūdžių įgijimas studijuojant mediciną

Gintaras Simutis[1], Mantas Drungilas[1], Pavel Petrik[2], Eglė Petrik[3],
Virgilijus Beiša[1], Kęstutis Strupas[1]

[1] *Clinic of Gastroenterology, Nephrourology and Surgery, Center of Abdominal Surgery, Faculty of Medicine, Vilnius University, Santariškių Str. 2, LT-08661 Vilnius, Lithuania*
[2] *Clinic of Gastroenterology, Nephrourology and Surgery, Center of General Surgery, Faculty of Medicine, Vilnius University, Šiltnamių Str. 29, LT-04130 Vilnius, Lithuania*
[3] *Department of Physiology, Biochemistry and Laboratory Medicine, Center of Laboratory Medicine, Faculty of Medicine, Vilnius University, Santariškių Str. 2, LT-08661 Vilnius, Lithuania*
El. paštas: Gintaras.Simutis@santa.lt

[1] *Vilniaus universitetas, Medicinos fakultetas, Gastroenterologijos, nefrourologijos ir chirurgijos klinika, Pilvo chirurgijos centras, Santariškių g. 2, LT-08661 Vilnius*
[2] *Vilniaus universitetas, Medicinos fakultetas, Gastroenterologijos, nefrourologijos ir chirurgijos klinika, Bendrosios chirurgijos centras, Šiltnamių g. 29, LT-04130 Vilnius*
[3] *Vilniaus uiversitetas, Medicinos fakultetas, Fiziologijos, biochemijos, mikrobiologijos ir laboratorinės medicinos katedra, Laboratorinės medicinos centras, Santariškių g. 2, LT-08661 Vilnius*
El. paštas: Gintaras.Simutis@santa.lt

Background / objective

The study was carried out to evaluate the potential use of laparoscopic simulators to enhance basic laparoscopic skills until proficiency is reached.

Materials and methods

The study participants were divided into two groups according to their experience in laparoscopic procedures: no prior experience (group A; n = 16) and laparoscope navigation experience (group B; n = 16). All the participants performed nine attempts of three basic laparoscopic skill tasks ("Instrument navigation", "Cutting", "Clip applying") on the LapSim® simulator during three sessions within one month. The distribution of practice sessions was standardized by performing three attempts for each task per session and no more than one session per week. The assessment of laparoscopic skills was based on the cumulative score for each task measured by the computer system.

Results

Trainees in the group A were younger (22.2 ± 1.3 vs. 26.1 ± 1.3 years, $P < 0.001$). There were statistically significant differences in cumulative scores for all three tasks after the first five attempts between the two groups ($P < 0.001$). Comparison of the cumulative scores for the task "Instrument navigation" after the sixth attempt ($P = 0.073$), for the task "Clip applying" after the seventh attempt (P = 0.287), and for the task "Cutting" after the eighth attempt (P = 0.080) showed no significant differences among the study groups.

Conclusions

The results indicated that a group of trainees with no prior laparoscopic experience acquired the basic laparoscopic skills significantly faster. Proficiency in the laparoscopic basic tasks was achieved within 6–8 repetitions in both groups. These findings suggest that training of practical skills in using laparoscopic simulators should be integrated into medical education much earlier.

Key words: surgical education, simulation, laparoscopy, virtual reality simulator, LapSim

Tikslas

Atlikti tyrimą, siekiant įvertinti kompiuterinių laparoskopinių simuliatorių naudojimą medicinos studijoms mokant pagrindinių laparoskopinių operacijų įgūdžių, kol bus įgyta reikiama patirtis.

Metodika

Tyrimo dalyviai pagal patirtį buvo suskirstyti į dvi grupes: vienos grupės tiriamieji neturėjo jokios išankstinės laparoskopinių operacijų patirties (A grupė, n=16), o kitos grupės turėjo tik navigacijos laparoskopu patirties (B grupė, n=16). Visi dalyviai per trejas pratybas su laparoskopiniu virtualiu simuliatoriumi LapSim® atliko trijų pagrindinių laparoskopinių užduočių („Instrumentų navigacija", „Pjovimas", „Kabučių uždėjimas") devynis bandymus. Kiekvieną užsiėmimą atskira užduotis buvo kartojama tris kartus, o užsiėmimas vyko ne dažniau nei kartą per savaitę. Vertintas galutinis užduoties rezultatas. Laparoskopinių operacijų įgūdžiai vertinti kompiuterine sistema pagal išvestinį kaupiamąjį kiekvienos užduoties balą.

Rezultatai

A grupės dalyviai buvo jaunesni (22,2±1,3 vs. 26,1±1,3 metų, p<0,001). Išanalizavus visų trijų užduočių kaupiamuosius balus po pirmųjų penkių bandymų, abi grupės skyrėsi statistiškai reikšmingai (p<0,001). Tyrimą tęsiant ir lyginant išvestinį kaupiamąjį balą atliekant užduotį „Instrumentų navigacija" po šešto bandymo (p=0,073), užduotį „Kabučių uždėjimas" po septinto bandymo (p=0,287), užduotį „Pjovimas" po aštunto bandymo (p = 0,080), jokių reikšmingų skirtumų tarp tiriamų grupių nerasta.

Išvados

Tyrimo rezultatai parodė, kad net be laparoskopinių operacijų patirties tokių operacijų pagrindinius įgūdžius laparoskopiniu simuliatoriumi įgyjama greičiau. Chirurginės simuliacijos užduočių kartojimas iki 6–8 bandymų leidžia įgyti gerus pagrindinių laparoskopinių operacijų įgūdžius. Šie rezultatai rodo, kad praktinių įgūdžių mokymas naudojant laparoskopinį simuliatorių turėtų būti įtrauktas į medicinos studijų programą.

Reikšminiai žodžiai: chirurgijos studijos, simuliacija, laparoskopija, virtualios realybės simuliatorius, LapSim.

Introduction

Laparoscopic surgery has become a new standard in many operations and positively affects patient outcomes, but has also introduced new skill sets that need to be mastered. In contrast to open surgery, laparoscopic surgery allows the handling of organs only with instruments managed through small holes in the abdominal wall; this reduces motion freedom, the tip of the instrument is moved in the direction opposite to the surgeon's hand, and the loss of depth perception due to the two-dimensional imaging makes laparoscopic techniques difficult to acquire and necessitate dedicated training [1–2].

The absence of appropriate training can compromise patient safety, which has been evident from the early experience with laparoscopic cholecystectomy [3]. However, although the need for additional training exists, the operating room may be a less than ideal learning environment due to time and fiscal limitations and in addition to ethical and medico-legal concerns of learning new skills on actual patients. Teaching and evaluation of technical skills outside the operating room has become very important in modern surgical education. Laparoscopic simulators currently can be used for initial training in simulated setting and without any risk to patients.

There are a few kinds of laparoscopic simulators, a high-fidelity virtual reality (VR) simulator and low-fidelity physical models. Simulation using physical objects usually involves models of plastic, rubber and latex, which are used to render different organs and pathologies, allowing a trainee to perform specific tasks and procedures. Several VR simulators (MIST-VR [Minimally Invasive Surgery Trainer-Virtual Reality], LapSim®, SimSurgery®, Lap-Mentor®) currently are available for surgical simulation. VR simulators are designed to measure instrument handling and effectiveness, the time to complete tasks, errors and the use of electrocautery. Basic and procedural tasks can be simulated in a high-fidelity virtual environment that is closely similar to the operative field. First studies using VR simulators have shown that practice on a simulator leads to an improved performance of similar tasks in the operating room [4, 5]. Moreover, it is at least as effective as video training in supplementing standard laparoscopic training [5]. Additionally, VR simulators may be useful in the objective assessment of competence, progression, and maintenance of technical skills using detailed parameters. It has been shown that performance of various tasks on a laparoscopic surgical simulator corresponds to the respective level of laparoscopic surgery experience [6].

However, there is still a big question of how in the future to select candidates for laparoscopic training and which characteristics predict good surgical performance. Studies attempting to answer this question gave mixed results. Preliminary data suggest that age, gender, hand dominance, video and computer game experience, visual spatial perception, psychomotor aptitude, as well as academic achievements may contribute to the acquisition of laparoscopic technical skills [7, 8].

The purpose of the present study was to evaluate the application of a VR laparoscopic simulator to enhance the basic laparoscopic skills until proficiency was reached.

Materials and methods

The study was carried out at the Centre of Abdominal Surgery of the Vilnius University Hospital Santariskiu Clinics from November 2012 up to December 2012. Sixteen students (13 male, 3 female) with no prior experience in laparoscopic surgery were involved from the Faculty of Medicine of Vilnius University, and sixteen surgical residents (14 male, 2 female) from Vilnius University hospitals with laparoscope navigation experience participated in this study.

The study participants were divided into two groups according to their experience with laparoscopic procedures: no prior experience (group A; medical students; n = 16) and laparoscope navigation experience (group B; surgical residents; n = 16). None of the participants had any previous experience with the VR simulator. The nature of the study was explained to all subjects prior to enrolment. Questionnaires on the demographic, computer and video game experience variables had been completed before training.

The VR simulator used in this study was the LapSim® (Surgical Science, Gothenburg, Sweden) which consists of a computer-based platform and virtual laparoscopic interface (Fig. 1). The virtual laparoscopic interface contains two laparoscopic instruments and a diathermy pedal. All participants' movements are translated into a real-time

Fig. 1. The LapSim® virtual reality training system

graphic display. All subjects were given a brief introduction to the system, including task design and avoidance of errors, and were familiarized with the tasks of the LapSim® using the 15-minute introductory video material.

All the participants performed nine attempts of three basic laparoscopic skill tasks ("Instrument navigation" [IN], "Cutting" [C], "Clip applying" [CA]) on the LapSim® simulator during three sessions within one month. The distribution of practice sessions was standardized by performing three attempts for each task per session and no more than one session per week. The tasks were of constant difficulty. A description of each of the three LapSim® tasks is presented in Table 1. Assessment of skills was based on time, path length, angular path, and other parameters also are measured depending on the nature of each task. The total score represents a cumulative score of time and the economy of movements. All data were automatically measured and recorded by the simulator. The final data were based on the weighted score of displayed parameter score results.

All statistical analyses were performed using the SPSS software (version 20.0). Normally distributed continuous data are given as a mean ± standard deviation and non-normally distributed data as a median. The Mann–Whitney *U* test was used to evaluate continuous data differences in task performance between the two groups. Categorical data were analyzed using Fisher's exact test. The P value at the level of <0.05 was considered statistically significant.

Results

Medical students were younger than surgical residents (22.2 ± 1.3 years (range, 21–26 years) vs. 26.1 ± 1.3 years (range, 25–29 years), respectively, P < 0.001), and there were no gender difference between the two groups (13 (81.3%) males vs. 14 (87.5%) males, respectively, P = 1.000) (Table 2). Results of the questionnaire on computer and video game experience are shown in Table 2.

The overall performance scores were significantly different between medical students and surgical residents after the first-week session ("Instrument navigation" task – 100% vs. 76%, respectively, P < 0.001; "Cutting" task – 90% vs. 56%, respectively, P < 0.001; "Clip applying" task – 91% vs. 64%, respectively, P < 0.001) as well as after the second-week session ("Instrument navigation" task – 100% vs. 85%, respectively, P < 0.001; "Cutting" task – 95% vs. 70%, respectively, P < 0.001; "Clip applying" task – 98% vs. 70%, respectively, P < 0.001). A comparison of cumulative scores for all three basic laparoscopic tasks between the two study groups is presented in Table 3.

Table 1. Description of basic laparoscopic tasks performed on LapSim®

Task name	Task description	Displayed parameter
I. Instrument navigation	The task requires a participant to to touch the colored laparoscopic instrument tip to the gallstone	Left and right instrument time (s), misses (%), path length (m), angular path (degrees), tissue damage (#), and maximum damage (mm)
II. Cutting	The task requires a participant to grasp the vessel with the right instrument and apply thermocautery with the left instrument. A diathermy foot pedal is attached to the system and is pressed down to simulate the burning of the tissue	Total time (s), rip failure (%), drop failure (%), timeout failure (%), cutter path length (m) and angular path (degrees), grasper path length (m) and angular path (degrees), maximum stretch damage (%), tissue damage (#), and maximum damage (mm)
III. Clip applying	The task requires a participant to grasp the vessel with one instrument while applying clips to a predetermined marked area on the vessel. This manoeuvre is repeated at the other end of the vessel, with instruments reversed. When the clips are properly placed, the vessel is transected using scissors	Total time (s), incomplete target areas (#), badly placed clips (#), dropped clips (#), left and right instrument path length (m), angular path (degrees), maximum stretch damage (%) and blood loss (litre)

Table 2. Comparison of participants' characteristics

Characteristics	Group A (medical students) (n = 16)	Group B (surgical residents) (n = 16)	P value
Age in years (range)	22.2 ± 1.3 (21-26)	26.1 ± 1.3 (25–29)	< 0.001
Male : female	13 : 3	14 : 2	NS
Left hand dominace (n)	1	2	NS
Previous laparoscopic surgery experience, cases	0 ± 0	0 ± 0	NS
Some experience with VR games (n)	13 (81.3%)	14 (87.5%)	NS

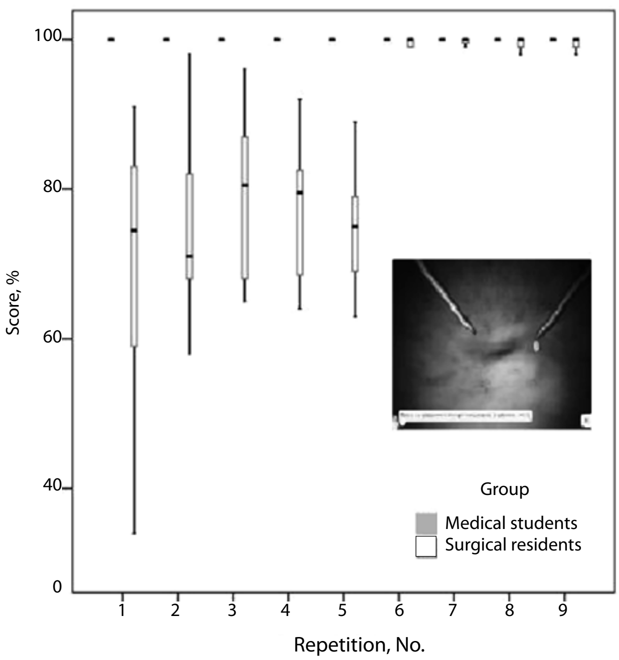

Fig. 2. Box plots of cumulative score for the "Instrument navigation" task showing the difference between groups A (medical students) and B (surgical residents) with an example of the graphical representation of the basic laparoscopic task "Instrument navigation" from the virtual reality simulator LapSim®

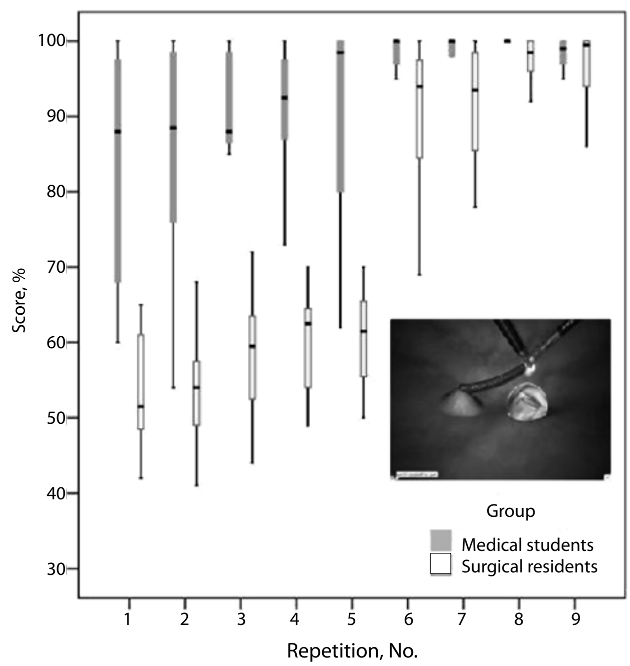

Fig. 3. Box plots of cumulative score for the "Cutting" task showing the difference between groups A (medical students) and B (surgical residents) with an example of the graphical representation of the basic laparoscopic task "Cutting" from the virtual reality simulator LapSim®

Trainees achieved similar cumulative scores for "Instrument navigation", "Cutting" and "Clip applying" on 6, 8 and 7 repetition, respectively, but group A outperformed group B during their first 5 repetitions (Fig. 2; Fig. 3; Fig. 4). There were no significant differences in the "Instrument navigation" task performance scores after the sixth attempt (100% vs. 100%, respectively, P = 0.073), in the "Cutting" task performance scores after the eight attempt (100% vs. 99%, respectively, P = 0.080), and in the "Clip applying" task performance scores after the seventh attempt (100% vs. 100%, respectively, P = 0.287) between medical students and surgical residents. After the three-week session, medical students were not superior to surgical

Table 3. Comparison of cumulative scores for all three basic laparoscopic tasks in two study groups

Exercise	Attempt	Medical students, score	Surgical residents, score	Difference, %	P value
“Instrument navigation”	1–3	100 (0)	76 (20)	24.0%	**< 0.001**
	4–6	100 (0)	85 (8)	15.0%	**< 0.001**
	7–9	100 (0)	100 (0)	0.0%	0.073
“Cutting”	1–3	90 (19)	56 (8)	34.0%	**< 0.001**
	4–6	95 (8)	70 (10)	25.0%	**< 0.001**
	7–9	100 (3)	96 (8)	4.0%	0.067
“Clip applying”	1–3	91 (17)	64 (8)	27.0%	**< 0.001**
	4–6	98 (10)	70 (3)	28.0%	**< 0.001**
	7–9	100 (4)	98 (4)	2.0%	0.094

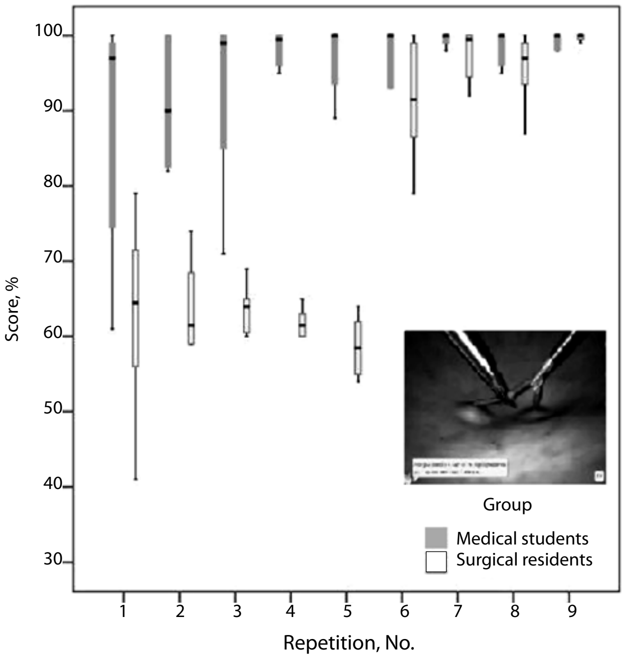

Fig. 4. Box plots of cumulative score for the “Clip applying” task showing the difference between groups A (medical students) and B (surgical residents) with an example of the graphical representation of the basic laparoscopic task “Clip applying” from the virtual reality simulator LapSim®.

residents in any of the three basic laparoscopic tasks (P > 0.05).

Discussion

Traditionally, it is supposed that a surgical resident becomes a proficient surgeon after performing a procedure or operation a certain number of times or after a certain length of training, usually after the residency, without an objective evaluation of the acquired skills. However, the variability in individual learning rates is not taken into account. Therefore, the majority of training in abdominal surgery still occurs on real patients during operations with a direct supervision of experienced surgeons. Assessment of acquired laparoscopic skills has become increasingly important because of the widespread use of laparoscopic surgery.

Moreover, reports of serious complications have emphasized the importance of a strict training and evaluation on surgical skills before practicing of real patients in the operating room. According to Rosser, a procedure-based technical skills training must begin by teaching the basic psychomotor skills, such as hand–eye coordination, the fulcrum effect and depth perception necessary for laparoscopic surgery [9].

One of the fortes of our study is that none of the participants had been previously exposed to virtual reality in laparoscopy. The results showed that younger medical students acquired laparoscopic technical skills significantly faster that surgical residents. The effect of age on acquiring laparoscopic skills has been shown in several recent studies [10–12]. Salkini et al. data have shown that younger individuals may be able to acquire laparoscopic skills faster and with more efficiency than older students and residents [11]. Moreover, Van Hove et al. in a series of studies of laparoscopic skills acquisition among 35 first-year surgical residents suggest that older residents beginning their surgical careers may be slower in developing technical skills required for laparoscopic surgery [12]. The authors found a negative correlation between trainee age and both the degree of improvement during training and the final scores.

This raises the question whether the innate abilities may predict an excellent acquisition of laparoscopic technical skills. Recently, many authors have reported the benefit of video, computer and television (TV) game use in training laparoscopic skills using a surgical simulator [12, 13]. According to Rosser et al., video game skills and the past video game experience are significant predictors of laparoscopic skills [14]. A study by Van Hove et al. indicates that a history of video game use correlates with significantly higher initial scores and a better retention of laparoscopic skills [12]. Other authors have recently concluded that medical students and experienced laparoscopic surgeons with an ongoing video game experience have superior laparoscopic skills for simulated tasks in terms of time to completion, improved efficiency and fewer errors as compared with non-gaming colleagues [15]. Moreover, a study from Japan by Nomura et al. reported that medical students who had an interest in TV games completed the task on a simulator in less time and had a shorter left instrument path length [16]. Another study has reported that spatial skills are essential for VR laparoscopic task performance, thus the use of computer games may contribute to the improvement of skills relevant for sufficient performance in VR laparoscopic tasks [17]. In contrast to the previous study, Kennedy et al. found that students who played video games for at least 7 hours per week demonstrated significantly better psychomotor skills than students who did not play video games regularly; however, the authors did not find any significant differences in data on visual and spatial perceptual abilities [18]. However, Adams et al. have shown that residents who engage in video games have a better visual, spatial and motor coordination [13]. Interestingly, most residents that participated in this study stated that playing video games helped to reduce stress; also, a cooperative play stimulated better relationships among colleagues.

Hand dominance was reported to influence skill acquisition during the basic laparoscopic skills training [8, 19]. Grantcharov et al. in their study showed that trainees with right hand dominance performed fewer unnecessary movements [8]. Moreover, the authors observed a trend towards better results in terms of time and errors among residents with right hand dominance than among those with left hand dominance. However, Powers et al. showed no difference in laparoscopic skills acquisition between right-handed and left-handed surgeons, although surgeons with left hand dominance demonstrated a better initial performance [19]. In our study, we did not evaluate the relation of hand dominance to overall performance scores of exercises due to the highly different percentages of right- and left-handed participants among both medical students and surgical residents.

Sleep deprivation and fatigue have been reported to influence the acquisition of laparoscopic skills [20, 21]. Call-associated sleep deprivation and fatigue are associated with increased technical errors in the performance of simulated laparoscopic technical skills [20]. According to Kahol et al., fatigue and sleep deprivation cause a significant deterioration in the surgical residents' cognitive skills [22]. As a result, psychomotor skills, which are essential for good performance, are negatively impacted during tasks that require a combination of psychomotor and cognitive skills. Similarly, negative effects on dexterity, error rate, mental workload and cognitive function have also been described [22, 23]. However, a number of studies focusing on motor skills did not show a significant negative effect of fatigue on task performance or skills acquisition [21, 24]. A recent study by Tomasko et al. showed that sleep-deprived subjects were able to complete the tasks despite an increased workload and were able to learn a new task proficiently despite an increased sleepiness [24].

At least one research showed that in motor skills acquisition of a basic task, the component of declarative learning, which appears to be influenced by the circadian rhythm, was influenced by the time of the day with better results in the morning, whereas the kinematic component of motor skills acquisition was independent of the time of the day [25]. However, a recent study by Bonrath et al., which was aimed to examine the difference in training effectiveness depending on the time of the day, using a VR simulator, showed that all participants significantly improved their technical skills throughout the training irrespective of the time of the day the training had been conducted [26]. Moreover, no differences were observed between the groups as regards the post-training skill levels. In our study, we did not evaluate individual attentiveness nor did we account for daily activities and work shifts. Consequently, we cannot exclude the possibility that participants in either group may have been more tired than others.

The other factors that may contribute to the development of skills which could be relevant for the performance of laparoscopic surgery are gender, choice of subspeciality, and even confidence in car driving [8, 12, 16, 27]. Gratcharov et al. found that men completed the tasks in less time than women, but there was no statistically significant difference between the genders in the number of errors and unnecessary movements [8]. However, a recent study from Canada, performed by Kolozsvari et al., showed that gender did not affect the learning curve for a fundamental laparoscopic task [27]. Van Hove et al. reported that medical interns designated for the general surgery training program had significantly higher final scores than those entering other fields [12]. Similarly, the previously mentioned study by Kolozsvari et al. reported that interest in surgery, as well as perceptual abilities influence the early performance of the basic laparoscopic skills [27]. According to Nomura, both students who were confident about driving and who thought themselves manually dexterous completed the task on laparoscopic simulator in less time [16].

Interestingly, recently Kuzbari et al. have reported that laparoscopic performance may be related to measures of the frontal lobe function [28]. This raises the larger question of how we may need to select future candidates for surgical training based, in part, on innate abilities, psychomotor information and skills acquisition.

Conclusions

The results of our study demonstrate that a group of trainees with no prior laparoscopic experience acquired basic laparoscopic skills significantly faster. Proficiency in the laparoscopic basic tasks was achieved within 6–8 repetitions in both groups. These findings suggest that practical skills training using laparoscopic simulators should be integrated into medical education much earlier.

REFERENCES

1. Gallagher AG, McClure N, McGuigan J, Ritchie K, Sheehy NP. An ergonomic analysis of the fulcrum effect in the acquisition of endoscopic skills. Endoscopy 1998; 30: 617–20.
2. Perkins N, Starkes JL, Lee TD, Hutchison C. Learning to use minimal access surgical instruments and 2-dimensional remote visual feedback: how difficult is the task for novices? Adv Health Sci Educ Theory Pract 2002; 7: 117–31.
3. Barone JE, Lincer RM. A prospective analysis of 1518 laparoscopic cholecystectomies. The Southern Surgeons Club. N Engl J Med 1991; 324: 1073–8.
4. Grantcharov TP, Kristiansen VB, Bendix J, Bardram L, Rosenberg J, Funch-Jensen P. Randomized clinical trial of virtual reality simulation for laparoscopic skills training. Br J Surg 2004; 91: 146–50.
5. Seymour NE, Gallagher AG, Roman SA, O'Brien MK, Bansal VK, Andersen DK, Satava RM. Virtual reality training improves operating room performance: results of a randomized, double-blinded study. Ann Surg 2002; 236: 458–63.
6. Gurusamy K, Aggarwal R, Palanivelu L, Davidson BR. Systematic review of randomized controlled trials on the effectiveness of virtual reality training for laparoscopic surgery. Br J Surg 2008; 95(9): 1088–97.
7. van Dongen KW, Tournoij E, van der Zee DC, Schijven MP, Broeders IA. Construct validity of the LapSim: Can the LapSim virtual reality simulator distinguish between novices and experts? Surg Endosc 2007; 21: 1413–7.
8. Grantcharov TP, Bardram L, Funch-Jensen P, Rosenberg J. Impact of hand dominance, gender, and experience with computer games on performance in virtual reality laparoscopy. Surg Endosc 2003; 17(7): 1082–5.
9. Rosser JC, Rosser LE, Savalgi RS. Skill acquisition and assessment for laparoscopic surgery. Arch Surg 1997; 132: 200–4.
10. Salkini M, Knapp A, Hamilton A. Laparoscopic simulation, who can be trained? Simul Healthc 2006; 1(2): 111.
11. Salkini MW, Hamilton AJ. The effect of age on acquiring laparoscopic skills. J Endourol 2010; 24(3): 377–9.
12. Van Hove C, Perry KA, Spight DH, Wheeler-Mcinvaille K, Diggs BS, Sheppard BC, Jobe BA, O'Rourke RW. Predictors of technical skill acquisition among resident trainees in a laparoscopic skills education program. World J Surg 2008; 32(9): 1917–21.
13. Adams BJ, Margaron F, Kaplan BJ. Comparing video games and laparoscopic simulators in the development of laparoscopic skills in surgical residents. J Surg Educ 2012; 69(6): 714–7.
14. Rosser JC, Lynch PJ, Cuddihy L, Gentile DA, Klonsky J, Merrell R. The impact of video games on training surgeons in the 21st century. Arch Surg 2007; 142: 181–6.

15. Ou Y, McGlone ER, Camm CF, Khan OA. Does playing video games improve laparoscopic skills? J Surg Educ 2013; 11(5): 365–9.

16. Nomura T, Miyashita M, Shrestha S, Makino H, Nakamura Y, Aso R, Yoshimura A, Shimura T, Akira S, Tajiri T. Can interview prior to laparoscopic simulator training predict a trainee's skills? J Surg Educ 2008; 65(5): 335–9.

17. Rosenthal R, Geuss S, Dell-Kuster S, Dell-Kuster S, Schäfer J, Hahnloser D, Demartines N. Video gaming in children improves performance on a virtual reality trainer but does not yet make a laparoscopic surgeon. Surg Innov 2011; 18: 160–70.

18. Kennedy AM, Boyle EM, Traynor O, Walsh T, Hill AD. Video gaming enhances psychomotor skills but not sisuospatial and perceptual abilities in surgical trainees. J Surg Educ 2011; 68(5): 414–20.

19. Powers TW, Bentrem DJ, Nagle AP, Toyama MT, Murphy SA, Murayama KM. Hand dominance and performance in a laparoscopic skills curriculum. Surg Endosc 2005; 19(5): 673–77.

20. Eastridge BJ, Hamilton EC, O'Keefe GE, Rege RV, Valentine RJ, Jones DJ, Tesfay S, Thal ER. Effect of sleep deprivation on the performance of simulated laparoscopic surgical skill. Am J Surg 2003; 186(2): 169–74.

21. Uchal M, Tjugum J, Martinsen E, Qiu X, Bergamaschi R. The impact of sleep deprivation on product quality and procedure effectiveness in a laparoscopic physical simulator: a randomized controlled trial. Am J Surg 2005; 189: 753–7.

22. Kahol K, Leyba MJ, Deka M, Deka V, Mayes S, Smith M, Ferrara JJ, Panchanathan S. Effect of fatigue on psychomotor and cognitive skills. Am J Surg 2008; 195(2): 195–204.

23. Grantcharov TP, Bardram L, Funch-Jensen P, Rosenberg J. Laparoscopic performance after one night on call in a surgical department: prospective study. BMJ 2001; 323: 1222–3.

24. Tomasko JM, Pauli EM, Kunselman AR, Haluck RS. Sleep deprivation increases cognitive workload during simulated surgical tasks. Am J Surg 2012; 203: 37–43.

25. Kvint S, Bassiri B, Pruski A, Nia J, Nemet I, Lopresti M, Perfetti B, Moisello C, Tononi G, Ghilardi MF. Acquisition and retention of motor sequences: the effects of time of the day and sleep. Arch Ital Biol 2011; 149: 303–12.

26. Bonrath EM, Fritz M, Mees ST, Weber BK, Grantcharov TP, Senninger N, Rijcken E. Laparoscopic simulation training: does timing impact the quality of skill acquisition? Surg Endosc 2013; 27: 888–94.

27. Kolozsvari NO, Andalib A, Kaneva P, Kaneva P, Cao J, Vassiliou MC, Fried GM, Feldman LS. Sex is not everything: the role of gender in early performance of a fundamental laparoscopic skill. Surg Endosc 2011; 25(4): 1037–42.

28. Kuzbari O, Crystal H, Bral P, Atiah RAA, Kuzbari I, Khachani A, Aslam MF, Minkoff H. The relationship between tests of neurocognition and performance on a laparoscopic simulator. Minim Invasive Surg 2010; 48: 61–74.