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ORIGINAL ARTICLE

L. Mettler · N. F. Zuberi · P. Rastogi · T. Schollmeyer

Role and value of laparoscopic training devices in assessing nondominant and two-handed dexterity

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Abstract *Background and objectives:* To determine improvement in hand dexterity with targeted laparoscopic skill exercises desirable for use in the operating rooms among in-training laparoscopic gynaecological surgeons and medical students. *Design:* Cross-sectional study with paired analysis. *Setting:* Kiel School of Gynaecological Endoscopy and Reproductive Medicine, Germany, between February and April 2005. *Subjects:* Twenty third-year medical students and 20 in-training gynaecological endoscopic surgeons from various parts of the world. *Interventions*: Demonstration and explanation of a set of five laparoscopic skill exercises desirable for use in the operating rooms before administering a pretest. This was followed by voluntary practice of these exercises for at least 10 times over 1 day. The posttest was performed the next day once the participant was comfortable performing the skill. Pre- and posttest assessments were conducted by independent supervisors. *Main outcome measures:* Time to completion of tasks with minimal errors. *Results:* There was significant reduction in mean time for all the laparoscopic skill exercises performed with dominant, nondominant, and both hands, before and after the training and practice (p-value <0.01; paired t-test). Moderate to high correlation (0.617–0.901) was seen with the intermediate and complex/difficult tasks, whereas low correlation was seen with the simple/easy task (0.200–0.336). Medical students and gynaecologists both showed improvement in performance from pretest to posttest in terms of reduction in mean time taken to perform all the tasks with minimal errors. *Conclusions:* Simple laparoscopic training devices can substantially help an individual hand's improvement and acquisition of laparoscopic skills. Simple laparoscopic training devices along with animal models will continue to provide an efficient and effective environment for learning and teaching laparoscopic surgical skills. With this training, performance improves progressively with practice.

Keywords Laparoscopy · Skill training · Training models · Box trainers

Introduction

Laparoscopy training devices are progressively evolving towards full-scale laparoscopy simulators so as to be able to provide highly efficient and effective means of training professional behaviours. Numerous comparisons have been done to date to objectively assess desirable laparoscopic skills, and these can be reproduced and interpreted easily along with validation of the simulators used [1–5]. These skills include nondominant hand dexterity and two-handed choreography against a two-dimensional background that alters depth perception [6]. The goal of these devices is to develop the skills needed to perform surgical procedures via a minimal access approach.

Laparoscopic surgery mandates specialized dexterity beyond that of open surgery because of certain obstacles, including altered tactile feedback, different eye-hand coordination, translation of a two-dimensional video image into a three-dimensional working area, and the fulcrum effect [7, 8]. No evidence has been found for transferring learning from open experience to newly introduced laparoscopic knot-tying techniques [9], suggesting that specific training for minimally invasive

L. Mettler (✉) · T. Schollmeyer
Department of Obstetrics & Gynaecology, Campus Kiel,
University Hospitals Schleswig-Holstein,
Michaelisstr. 16,
24105 Kiel, Germany
e-mail: endo-office@email.uni-kiel.de
Tel.: +49-431-4972116
Fax: +49-431-5972116

N. F. Zuberi
Department of Obstetrics & Gynaecology,
Aga Khan University Hospital,
Stadium Road,
Karachi, 74800, Pakistan

P. Rastogi
Department of Obstetrics & Gynaecology,
SPS Apollo Hospitals,
Sherpur Chowk, G.T. Road,
Ludhiana, 141003, India

surgery training is necessary to develop laparoscopic surgery skills. Although first-generation laparoscopic trainers have been criticised as being unrealistic and lacking any form of objective assessment, they still remain an essential part of any laparoscopic skills training. A recent randomised controlled trial concluded that there appear to be no substantial advantages of available virtual reality trainers over the box trainers [10]. Laparoscopic operative skills are lacking in many countries. It is therefore important to develop and validate the desirable laparoscopic skills for nondominant hand dexterity and two-handed choreography against a two-dimensional background for the laparoscopic training devices, which can then be supplemented with rule-based and knowledge-based behaviours.

This study aimed to determine improvement in hand dexterity with targeted laparoscopic skill exercises desirable for use in the operating room among in-training gynaecological endoscopic surgeons and medical students.

Materials and methods

Design, setting, and subjects

This cross-sectional study was conducted between February and April 2005 at the Kiel School of Gynaecological Endoscopy and Reproductive Medicine, Germany. The study population consisted of third-year medical students (*n*=20) and in-training gynaecological endoscopic surgeons (*n*=20) who voluntarily participated. Medical students had no prior experience of handling laparoscopic tasks, whereas the in-training laparoscopic gynaecological surgeons had limited experience performing and assisting with laparoscopic gynaecological surgeries. Medical students were included as controls to determine the magnitude of prior knowledge and experience of open surgical procedures on the subsequent acquisition of laparoscopic skills.

Educational interventions and assessment tool

Each participant performed the predefined laparoscopic skill tasks before and after the educational intervention and practice. All participants received individual explanation and demonstration of the skill tasks along with what was expected from them. They were instructed to perform the task accurately and precisely, avoiding errors, just as they would during a real-life surgical situation. They were asked to practice at least 10 times before taking the posttest. All the tasks were performed and evaluated on the LapTrainer with SimuVision LTS-10 (Simulab, Seattle, WA, USA; Fig. 1). This trainer has the capability to videorecord and play back the performed tasks. But for generalisation to simple laparoscopic devices, pre- and posttest assessments were done personally by two independent supervisors.

Fig. 1 LapTrainer with SimuVision (tm) LTS-10

Laparoscopic skills task description

The tasks consisted of one simple task, two intermediate-level tasks, and two complex/difficult tasks. All the simple tasks and intermediate-level tasks were performed with the dominant hand and then with the nondominant hand, and the complex/difficult tasks were performed as two-handed dexterity skills.

Simple task: touching Touch 16 coloured plastic pegs (four red pegs, four blue, four yellow, and four black) on a white plastic board without tumbling them, initially with the dominant hand and subsequently with the nondominant hand

Intermediate-level task 1: pulling Take out 14 numbered flags in sequence from nail poles fixed over a plastic pegboard pattern (LapTrainer Skills Set 1, LTSSI-10, Simulab, Seattle, WA, USA), initially with the dominant hand and subsequently with the nondominant hand

Intermediate-level task 2: putting Place six rubber rings over the nail poles (LapTrainer Skills Set 1, LTSSI-10, Simulab, Seattle, WA, USA), which were assigned English language letters and fixed over a plastic board, thereby making a word requested by the assessor

Complex/difficult task 1: manoeuvring Pass a metal key (Key Trainer ST-10, Simulab, Seattle, WA, USA) of four flat and broad segments linked with thin segments from a flat keyhole placed at a 45-degree angle, using the dominant hand to push the key through the hole and the nondominant hand to receive the metal key from the keyhole

Complex/difficult task 2: intracorporeal suturing Place three intracorporeal knots over a sponge using 3-0 Vicryl (SH-1 plus 21.8-mm 1/2c round-body curved needle, Ethicon, Johnson & Johnson), using both hands

Main outcome measure

The study end point was time to completion with minimal errors. The criteria of minimal errors were the following:

- Harsh and uncontrolled movement of the left or right hand
- Abrupt entry or exit of the left or right hand's instrument
- Forceful touching of the object by the left or right hand's instrument (false depth perception)
- Lack of full orientation of the acting instrument (direction, i.e. left or right)
- Uncontrolled movement of the needle (i.e. missing or/ and lacerating the target when suturing)

Statistical analysis

For each laparoscopic skill task, means, SEM, and 95% confidence intervals (CI) were calculated. Mean time to completion of each task for each group was then plotted, and box-plots were compared. The Student paired *t*-test and bivariate correlation were used to analyse the difference between baseline and final results for each laparoscopic skill task. A *p*-value <0.01 was considered significant. The Statistical Package for Social Sciences (SPSS) 13.0 for Windows was used for data entry and analysis.

Results

All 40 participants who took part in the study completed the laparoscopic skill exercises. Two independent observers noted the time taken to perform the tasks with minimal errors. For all participants in the study, the right hand was the dominant one. Of the 20 medical students who took part in the study, nine were male (mean age 21.7±1.4 years) and 11 were female (mean age 21.1±1.7 years); of the 20 in-training gynaecological endoscopic surgeons, 10 were male (mean age 34.2±3.1 years) and 10 were female (mean age 31.4±2.3 years) (Table 1).

For the simple task of touching ability with laparoscopic instruments (both pretest and posttest), there was no overall difference in time taken to complete the task with minimal errors with the dominant hand or the nondominant hand. The overall difference in mean time for the intermediate-level tasks of pulling and putting abilities with the dominant hand was less than with the nondominant hand, while the overall difference in mean time for the complex/ difficult tasks of manoeuvring and intracorporeal suturing was less than for the nondominant hand (Table 1).

Medical students and gynaecologists both improved their performance from pretest to posttest in terms of reduction in mean time taken to perform all the tasks with minimal errors. For the individual tasks, both groups took similar time to perform the simple tasks, but for the intermediate-level and complex/difficult tasks, gynaecologists took shorter time than the medical students. Medical students had less variability in terms of standard deviations for the time taken to perform simple tasks than the gynaecologists, but they showed no reduction in variability in the posttest. Gynaecologists, although they had higher variability for the simple tasks, showed significant reduction in variability in the posttest for the dominant hand only. Although overall reduction in variability for the intermediate and complex/difficult tasks was minimal, there was significant reduction in variability for individual tasks performed by the gynaecologists compared with the medical students (Table 1).

Table 2 shows significant reductions in mean times for all the laparoscopic skill exercises performed with dominant, nondominant, and both hands before and after the training and practice ($p<0.01$; paired *t*-test). Moderate to

Table 1 Time interval (in seconds) between pre- and posttest results (delta times) of various laparoscopic skill exercises with minimal errors by the study participants

Laparoscopic skill exercises	Medical students (*n*=20)		Gynaecologists (*n*=20)		Overall (*n*=40)	
	Mean	SD	Mean	SD	Mean	SD
Simple task to assess individual hand performance						
Touching ability, right hand	7.90	1.91	10.60	3.44	9.25	.63
Touching ability, left hand	11.20	.93	11.85	1.10	11.33	.33
Intermediate-level tasks to assess individual hand performance						
Pulling ability, right hand	47.60	20.11	4.85	6.21	25.73	25.43
Pulling ability, left hand	25.20	4.40	10.25	12.41	17.73	10.17
Putting ability, right hand	16.30	1.57	4.95	2.25	10.63	3.89
Putting ability, left hand	12.20	1.74	13.45	5.44	12.82	.18
Complex/difficult tasks to assess both hands' coordination						
Manoeuvring ability	42.80	18.34	75.15	26.67	58.97	10.10
Suturing ability	24.00	2.34	60.90	55.02	47.45	30.31

Table 2 Correlation and mean change in performance (in seconds) of various laparoscopic skill exercises before and after training and practice (n=40)

	Mean	SEM	95% CI of difference		*p*-value	Correlation
			Lower	Upper		
Touching ability, right hand	9.25	1.43	6.37	12.13	.000	.200
Touching ability, left hand	11.52	1.55	8.39	14.66	.000	.336
Pulling ability, right hand	25.73	4.63	16.36	35.09	.000	.894
Pulling ability, left hand	17.73	3.64	10.36	25.09	.000	.901
Putting ability, right hand	10.62	2.35	5.87	15.38	.000	.813
Putting ability, left hand	12.83	4.56	3.61	22.04	.008	.617
Manoeuvring ability, both hands	58.98	8.47	41.84	76.11	.000	.681
Suturing ability, both hands	47.45	11.99	23.20	71.70	.000	.832

high correlation (0.617–0.901) was seen with the intermediate and complex/difficult tasks, whereas low correlation was seen with the simple task (0.200–0.336).

Discussion

One of the first simulation trainers, the Pelvi-Trainer, was invented by Semm and is still in use today. This model consists of a metal tub into which the organs are placed. A Plexiglas panel with holes for the trocars and camera covers the tub. Semm developed this trainer because, unlike with laparotomy, the art of pelviscopic surgery cannot be learned through assisting only. This trainer was designed as part of a three-stage plan, and it allows individuals to become gradually acquainted with the field of endoscopic surgery [11].

Since then, laparoscopic training devices have come a long way. Various exercises introduced by Semm have been modified and new ones added for training and assessing aspiring endoscopic surgeons. One of the latest inventions is the virtual laparoscopic interface.

In a recent editorial, Wright emphasised the importance of modular training, which may, along with simple practical training, help form a well-thought-out, practical, and cohesive training programme [12]. We too are proponents of a well-structured and evidence-based organisation of laparoscopic training programs and underscore the importance of developing efficient and effective learning tools.

In our study, we were able to demonstrate significant improvement in the performance of skills desirable for laparoscopic surgery by the use of simple laparoscopic training devices. Improved performance was observed for the dominant hand, nondominant hand, and for both hands' coordinated activities. We were able to show that these simple trainers can efficiently and effectively improve medical students' laparoscopic skills as well as the skills of in-training gynaecological endoscopic surgeons. This is an endorsement of the point of view that separate skill sets are required for endoscopic surgery [9]. In another study [10], both trained groups made significant improvements in all parameters measured. Compared with the controls, those using the box trainer performed significantly better on most of the parameters, whereas the LapSim group performed significantly better on some other parameters.

In our study, the simple tasks were performed with equal ease and with similar improvement patterns for both groups. However, for intermediate-level and complex/difficult tasks, the gynaecologists performed and improved their skills better than the medical students did. Exercises assessing the simple skill of touching ability with laparoscopic instruments led to relatively more improvement in nondominant hand performance. Compared with the dominant hand's performance, improvement was seen more in dominant hand performance for the exercise assessing pulling ability, while nearly equal improvement was seen with the exercise assessing putting ability. Based on these observations, special emphasis may be given to individual hand improvement in laparoscopic skill acquisition. It has been argued that it is difficult to assess individual hand performance with box trainers [13]. These exercises were selected because of their applicability in real-life surgical situations: touching ability as proxy for precisely touching the ureters for identification, pulling ability as proxy for stripping a cyst wall or for countertraction on tissues, putting ability as proxy for placing a cyst into a retrieval bag, manoeuvring ability as proxy for working in difficult angles in the pelvis, and suturing over sponge as proxy for intracorporeal suturing of tissues. Due to the shortage of time, the individual exercises were practised in our study only 10 times before the posttest. It has been shown in the literature that a lengthy learning curve exists for novices and may be seen throughout 30 repetitions and possibly beyond [14].

Minimal access has come of age in virtually every aspect of medicine, for diagnosis as well as for therapy. It is interesting to note that this new approach has been influential in changing the boundaries of traditional clinical specialities, just as changes have occurred for some time in basic science alignments. Nowadays, there is very little tolerance for limitations, adverse sequellae, or mortality related to any technology or practitioner whose results along the learning curve lead to complications or mortality. To solve some of the problems of the learning curve, various approaches have been used by practitioners, academic organisations, and industry. These approaches range from animate to inanimate laboratories, simulation, and proctoring [15].

For a broader vision, we need to critically appraise the interventions devised for similar situations in fields other than medicine. Pilot training in aviation with high-tech full-flight simulators has been investigated in depth [16] and has demonstrated the potential of developing full-scale laparoscopy simulators. Rasmussen's model of human behaviour [17], which provides a framework for defining the objectives, needs, and means of training methods, has been well utilised in aviation. Due importance to knowledge-based behaviours along with rule-based behaviours and skill-based behaviours was given for development of full-flight simulators [18–20], while current virtual reality laparoscopy simulators focus on skill-based behaviours and partly on rule-based behaviours.

In recent years, a number of virtual reality simulators have been developed and are now commercially available, including the MIST-VR laparoscopic simulator (Mentice, Gothenburg, Sweden), the LapSim laparoscopic trainer (Surgical Science, Gothenburg, Sweden), the Xitact LS500 laparoscopy simulator (Xitact, Morges, Switzerland), the Reachin laparoscopic trainer (Reachin, Stockholm, Sweden), the ProMIS surgical simulator (Haptica, Dublin, Ireland), the LapMentor (Simbionix, Cleveland, OH, USA), and the VSOne virtual endoscopic surgery training (VEST) system (Select IT VEST Systems, Bremen, Germany). All of these models have been evaluated in various studies for their efficiency and effectiveness in training laparoscopic surgeons. They can be grouped as second-generation virtual reality simulators with variable capabilities to simulate laparoscopic surgical situations and training.

We agree with the assessment that training of skill-, rule-, and knowledge-based behaviour requires different training modalities. Skill-based behaviour does not necessarily require a highly sophisticated means of training; a simple Pelvi-Trainer already suffices. To train knowledge-based behaviour outside the operating room and without using living animal models, a high-fidelity laparoscopic simulator that accurately imitates the surgical environment is needed [21]. Furthermore, human cadavers or live animal models may also be used for training, but may not get ethics approval in certain institutes and countries.

Simple laparoscopic training devices are valuable in assessing nondominant and two-handed dexterity. They can also substantially facilitate acquisition, planning, and assessment of laparoscopic surgical skills. With this training programme, performance improves progressively with practice. A virtual reality-based surgical simulator system offers a very elegant possibility for enriching and enhancing traditional education.

The technological innovations in surgery are only beginning. The future will be very attractive, and the potential is enormous.

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