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ORIGINAL ARTICLE

Face and construct validation study of novel 3D peg transfer models for training and evaluation of laparoscopic skills in two-dimensional and three-dimensional laparoscopic surgery

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Abstract

Background: Fundamentals in Laparoscopic Surgery (FLS) is widely used in practice for skill acquisition and objective assessments. The peg transfer model enables trainees to acquire basic laparoscopic skills. We structured three different three-dimensional (3D) peg transfer models with various heights and depths to replicate 3D laparoscopic anatomy. Before implementing any simulation model in a laparoscopy curriculum, it is important to determine its validity. **Aim:** To establish face and construct validity of novel 3D peg transfer models in two-dimensional (2D) and 3D visual systems for training and evaluation of laparoscopic skills in novices using the McGill inanimate system. **Methods:** Three peg transfer 3D models were designed with different peg heights and depths using wooden blocks from the popular game "Jenga". Ten novices, ten intermediates and ten experts were recruited. They performed three repetitions of peg transfer on each model using 3D and 2D visual modalities. Performance time, error and total score were measured. Multiple comparison (post hoc Bonferroni) tests were used to compare the data (mean value of total time, total errors and total score) for each group. All participants completed a six-question post-test questionnaire (face validity) for 2D and 3D viewing modalities. **Results:** When novices were compared with intermediates and experts using 2D and 3D visual systems, there were statistically significant differences ($P < 0.001$) in the total score and performance time for all models with the exception of model 2 in 2D. We were unable to show any significant difference in total score and performance time when intermediates were compared with experts with any of the three models, in either the 2D or the 3D visual modality. All models were highly rated in both visual modalities. **Conclusion:** Three models were developed for improving laparoscopic surgical skills. Face validity and construct validity were demonstrated by measuring significant differences in improvement of performance time and lower total score when novices were compared with intermediates and experts in both 2D and 3D visual modalities. We recommend using models 1 and 3 for simulation training in both visual modalities, and this could replace the current relatively "flat" 2D models of the FLS training course to shorten the learning curve for acquiring surgical skills.

Keywords: *FLS; three-dimensional models; two-dimensional models; peg transfer; novices; surgical skills; validity*

Background

Standard laparoscopic surgery is practiced in two dimensions. This requires training and practice over significant periods to develop complex hand–eye coordination, depth perception and bimanual skills. Technological improvement has been consistent over the years, particularly with respect to monitors and videoscopy used in laparoscopic surgery. Nevertheless, training is challenging. We are currently facing a global shortage of medical professionals and, in addition, there is an increasing demand for better quality training. There is an absolute requirement to fast track training to gain the skills required for laparoscopic surgery.

Surgical simulation is now a well-established mode of training. Simulation is being widely used for training of a variety of skills in different specialities.[1–3] Various low-cost and high-fidelity simulators and training models are available on the market. Simulation technologies incorporate diverse products involving computer-based virtual reality simulators, high-fidelity and static mannequins, plastic or synthetic models, live animals or animal products, and human cadavers, most of which are not very cost-effective.[4]

The Society of American Gastrointestinal and Endoscopic Surgeons created an educational programme called Fundaments in Laparoscopic Surgery (FLS).[5] This programme is based on a series of validated exercises, developed for acquiring laparoscopic surgical skills.[5] With the use of FLS, acquisition of skills can be measured in a qualitative and objective way, based on efficiency and precision in performing the surgical tasks.[6–8] Seventeen (74%) studies[9] showed that total FLS skills scores discriminate between levels of training (usually different postgraduate years), offering weak but supportive evidence of validity.

During laparoscopic surgery, three-dimensional (3D) features simplify the appreciation of essential structures and anatomical features and provide visual spatial guidance, which is vital for the ongoing learning process of minimizing damage.[10] Several studies have suggested that 3D imaging facilitates the execution of complex tasks with improved performances.[11–16]

Previous studies[17,18] have suggested that 3D would not provide any benefits for experienced surgeons, due to their extensive experience with 2D laparoscopy. On the other hand, other recent studies have successfully shown improved performances of experienced surgeons when 3D imaging was used.[19–21] Thus, we postulate that a more truly 3D training model could accelerate learning and skills acquisition.

"Operational validation is determining whether the simulation model's output behaviour has the accuracy required for the model's intended purpose over the domain of the model's intended applicability".[22] A model's intended use is frequently tested under different experimental conditions. A model may be valid for one sort of training but could be worthless for another.[22]

With this in mind, we aimed to develop new cost-effective training models for peg transfer, which would be better suited for acquiring surgical skills in both 2D and 3D with particular emphasis on improving depth perception for novices. The aim of this study was to establish face and construct validity of three new 3D peg transfer models in 2D and 3D visual systems using the McGill Inanimate System for Training and Evaluation of Laparoscopic Skills.

Methods

The study was performed in the teaching centre of Barts Cancer Institute, Queen Mary University of London, and was planned in accordance with the CONSORT statement (Fig. 1). This was a prospective study into which 30 participants (novices, intermediates and experts) who fulfilled the inclusion criteria were recruited.

Laparoscopic simulator task

The study task was based on the FLS peg transfer task.[5] We set errors and penalty scores for each task as per the FLS curriculum (Table 1). Novel 3D models were used in a box trainer for acquiring laparoscopic skills such as bimanual skills, hand–eye coordination and depth perception.

The task involved bimanual laparoscopic manipulation of rubber pegs. Using a grasper/dissector, the resting peg had to be lifted with the non-dominant hand, transferred to the dominant hand, and placed on the opposite side of the board. Each transfer had to be made in mid-air. Once all the pegs had been transferred, the process was reversed thus returning the pegs to their original place.[5]

2D model

The 2D (FLS) model consisted of a flat white board with 12 posts spaced equally in different patterns on the right and left sides. The model is all arranged on a flat surface and therefore does not provide a view of working at different depths.

Development of 3D peg models

A team of laparoscopic experts and our research team together developed the 3D peg transfer models made up of wooden blocks (length 7.5 cm, width 2.5 cm, height 1.5 cm) from the widely available game "Jenga" with different heights and depths. The models were easy to make using the Jenga bricks. Screws were fixed at right angles to the wooden bricks. These models could easily be developed using any wooden blocks.

Model 1

This model was built in a step pattern. It had three steps with three posts installed on each step. Steps were built to give the model different depths and heights. Manoeuvring between steps would mimic manipulation to different heights.

Six pegs were placed on the lower two steps. The candidate transferred pegs from the middle step to the upper step. Once all three pegs were moved to the upper step, the candidate moved the pegs on the lower step to the middle step. This process was reversed to bring all six pegs back to their original places.

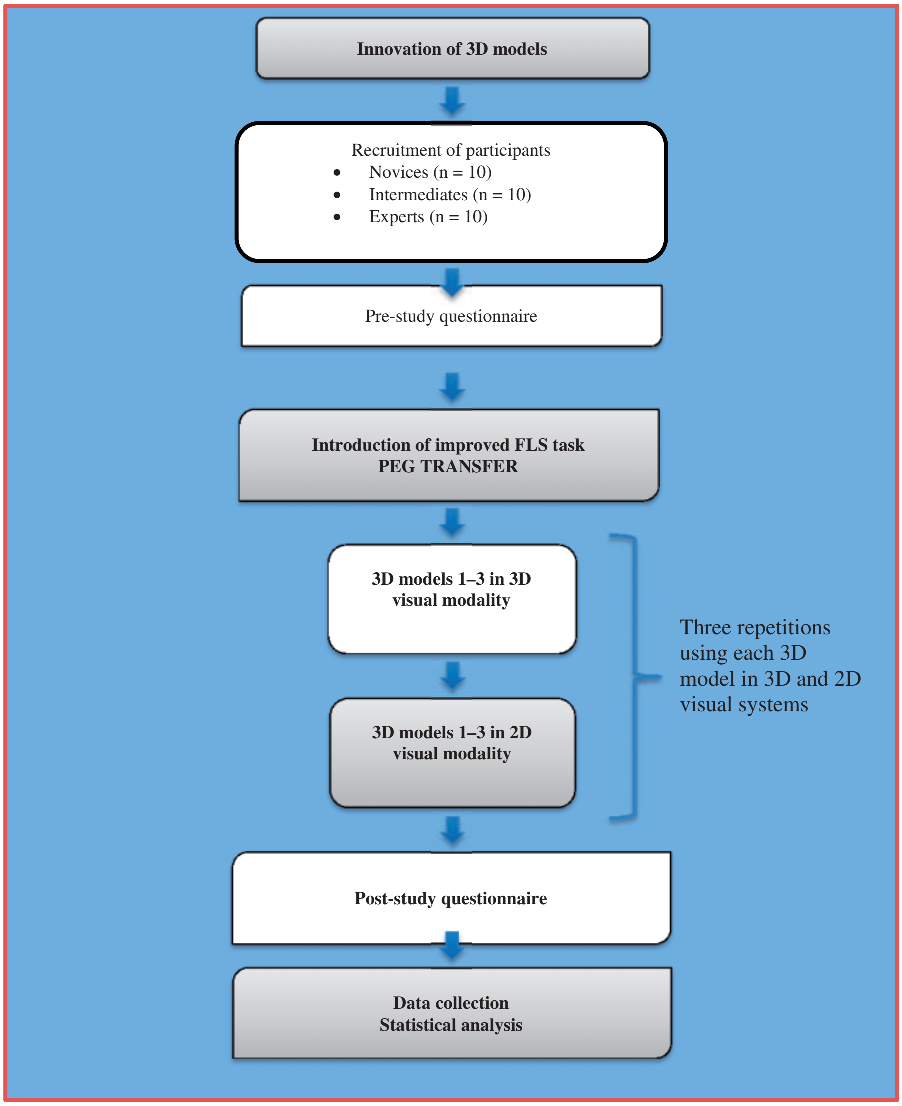


Figure 1. CONSORT chart.

Model 2

This model comprised two vertical towers at the back and one vertical and horizontal tower on top of each other at the front. This arrangement forms a small step at the back between two long towers. It is fairly difficult to reach that area. Six rubber pegs can be used. This variation was developed to simulate depth perception. Also, it can replicate working at different heights in the laparoscopic visual field.

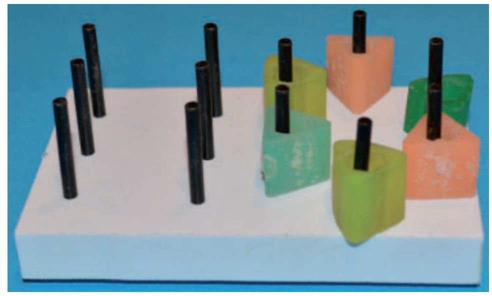
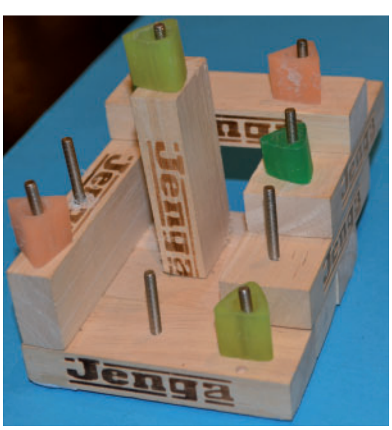
Three pegs were placed on the left side and another three were on the middle steps. Pegs on the middle steps were first transferred to the adjacent right-side steps. Similarly, left-side pegs were moved to middle steps. This process was revered to transfer all pegs back to their original positions.

Model 3

This model had a vertical tower in the centre with one post on top, a step pattern on the left side consisting of three posts, and one horizontal tower on the right side on which two posts are mounted. There were five pegs to be manoeuvred. This model was created to replicate depth perception at different levels.

Three pegs were mounted on the left-side steps and the remaining two were placed on the middle steps. Three pegs were transferred from the steps on the left to the right-side steps. The middle top peg was transferred to the bottom right step and the middle lower step peg was transferred to the top middle step. This process was reversed to arrange the pegs into their original positions.

Table 1. The three 3D models and the 2D FLS model for the peg transfer task

Novel 3D models	FLS 2D model	Task
Model 1 		**Task**: Pick the peg up with non-dominant hand, transfer it to dominant hand and drop it on the post **Materials**: Right angle screws on a wooden block peg board. **Errors and penalty scores:** Dropping a peg: (a) inside the field of vision (10 points); (b) outside the field of vision (20 points)
Model 2 		
Model 3 		

Assessments

We collected the data by measuring the following:

(1) Total score: penalty score + performance time

(2) Performance time: timing for this task began when the first object was touched; timing ended when the last object was released

(3) Errors and penalty scores: dropping a peg: (a) inside the field of vision = 10 points; (b) outside the field of vision = 20 points

Equipment

2D training

(1) Box trainer: LaproTrain by Endosim (52 × 38 × 24 cm^3) with five different port accesses (with a 2D camera attached)

(2) Monitor: LG 32LW450U, screen size 32 inches, LED TV (high definition, resolution 1920 × 1080; Motion Clarity Index, 400 Hz)

(3) Camera: attached to a box trainer

3D training

(1) Box trainer: LaproTrain by Endosim (52 × 38 × 24 cm^3) with five different port accesses

(2) Monitor: LG 32LW450U, screen size 32 inches, 3D LED TV (high definition, resolution 1920 × 1080; Motion Clarity Index, 400Hz)

(3) Camera: Sony camcorder HDR-TD10 Handycam, 10× optical zoom in 3D. The monitor was kept 2 m from the participant. Shutter glasses: LG passive 3D glasses; weight 16 g)

Study population

This study included individuals from three different categories: novice, intermediate and expert (Table 2). The novice group (n = 10) included medical students and foundation trainees (FY1 and FY2); the intermediate group (n = 10) comprised surgical trainees, including core surgical trainees (CT1, CT2) as well as specialist trainees (ST3, ST4); the expert group (n = 10) comprised specialist trainees at the level of ST5 and above.

As shown in the CONSORT diagram (Fig. 1), the study began with recruitment. The candidates completed the pre-study survey in which they answered questions on their demographics and their previous simulation and surgical experience (mainly laparoscopic).

Training session

Construct validity

Before each stage, every participant was shown an introductory video explaining the tasks and given a verbal explanation, including handling of instruments in order to guarantee the reproducibility of the instructions. In addition, a written descriptive document on each task along with possible errors was given to each participant (Fig. 1). One FLS trained instructor carried out one-to-one demonstrations in order to eliminate likely bias.

To familiarize them with the equipment, the novice group performed a task twice on model 1 and the other two groups performed it only once. All participants began the training using the 3D visual modality followed by the 2D modality. Each participant performed three repetitions of the task on each model in both visual systems. Data were collected for time to complete the task and the number of errors (penalties).

Table 2. Detailed characteristics of the participants in each category

Novice	Intermediate	Expert
Medical students and foundation trainees (years 1 and 2)	Core surgical trainees (years 1 and 2); specialist trainees (years 3 and 4)	Laparoscopic surgeons (ST5 and above) who are well recognized in their field and had previously performed a minimum of 200 laparoscopic procedures
	<20 surgeries assisted/performed	
No experience of laparoscopic simulation or laparoscopic surgery	Ability to perform basic surgery independently	Engaged in teaching and training trainees in specific laparoscopic courses
	Simulation experience >3 h	Minimal simulation exposure
	8 of 10 participants had <12 months of laparoscopic experience; 2 had been practicing for more than a year	No exposure to 3D laparoscopic system

Inter-sessional questionnaire

A questionnaire was used to record whether any side effects occurred while the candidate was undertaking the training using the 3D system. Between sessions, each participant was asked to list any side effects they had noticed during their use of the 3D visual system.

Face validity

Face validity was established by participants completing post-test questionnaires (Fig. 2) for the two different viewing modalities. The participants were asked to rate each model for its appearance, instrument handling, usefulness for hand–eye coordination, depth perception and other manual skills required for each task. They were also asked to rate whether the models are good enough to test the use of both hands.

Statistics

Data were collected for time to complete the task and the number of errors (penalties). The total (time) score was evaluated by adding the number of errors to the time to complete the task. A lower score reflects better performance. The results were initially collected in Excel spreadsheets (Excel for Windows Microsoft Corporation, Redmond, WA, USA) and then transferred to Graph Pad Prism 6 (GraphPad Software, San Diego, Ca, USA). One-way analysis of variance (ANOVA) with multiple comparisons (post hoc Bonferroni test) was used to analyse the differences between the three groups (construct validity). P values <0.05 were considered to be statistically significant; alpha was set at the 0.05 level.

Results

Thirty participants (ten novices, ten intermediates, ten experts) completed the study, in both visual modalities. The demographic data (Table 2) showed that intermediates had more training experience on box trainers and with virtual reality than the experts. A few experts had had minimal exposure to 3D laparoscopic training.

Construct validity: novel 3D models 1–3 in 2D and 3D visual modalities

Mean total score in 3D and 2D visual modalities

When the participants used the 3D visual system, we were able to show a statistically significant difference in total score when we compared novices with intermediates and experts for all three new models: group 1 versus 2 (novices versus intermediates) ($P < 0.05$) and group 1 versus 3 (novices versus experts) ($P < 0.05$).

When they used the 2D visual system, we were able to show a statistically significant difference in total score only in models 1 and 3 when we compared novices with intermediates and experts: group 1 versus 2 (novices versus intermediates) ($P < 0.05$) and group 1 versus 3 (novices versus experts) ($P < 0.05$). For model 2, in 2D, a statistically significant difference was only noted when comparing novices with experts; there was no difference in the score when comparing novices with intermediates (Table 2).

There was no difference in total score when we compared intermediates with experts for any of the models using either the 2D or the 3D visual system (Table 3).

Mean total performance time in 3D and 2D visual modalities

When the participants were using the 3D visual system, we were able to show a statistically significant difference in total performance time when we compared novices with intermediates and experts for all three new models: group 1 versus 2 (novices versus intermediates) ($P < 0.05$) and group 1 versus 3 (novices versus experts) ($P < 0.05$).

When they used the 2D system, we were able to show a statistically significant difference in performance time only on models 1 and 3 when we compared novices with intermediates and experts: group 1 versus 2 (novices versus intermediates) ($P < 0.05$) and group 1 versus 3 (novices versus experts) ($P < 0.05$). For model 2, used with the 2D visual system, a statistically significant difference was only noted when comparing novices with experts with no significant difference in score when comparing novices with intermediates (Table 4).

Q	Face validity questionnaire	Likert scale (score 1–5)
Q1	How realistic they look	
Q2	How realistic is instrument handling	
Q3	Usefulness of 2D/3D hand–eye coordination	
Q4	Ability to perceive depth in 2D\3D	
Q5	How well the model represents manual skills required for peg transfer	
Q6	How well the model tested use of both hands	

Figure 2. Face validity questionnaire, rated using a Likert scale (1–5)

Table 3. Construct validities: total score = performance time + penalties for performance for models 1–3 in 3D and 2D visual modalities

Exercises	Total score, mean (range)			ANOVA *P* value	Multiple comparison Tukey test		
	Group 1: novices (n = 10)	Group 2: intermediates (n = 10)	Group 3: experts (n = 10)		Comparison	Significant yes/no	*P* value
Peg transfer: 3D visual modality							
Model 1	191.8 (155–285)	116 (61–168)	122.4 (87–153)	< 0.0001	Group 1 vs. 2 Group 1 vs. 3 Group 2 vs. 3	Y Y N	< 0.001 < 0.001 > 0.05
Model 2	159.2 (133–196)	126 (75–161)	133.2 (121–142)	0.008	Group 1 vs. 2 Group 1 vs. 3 Group 2 vs. 3	Y Y N	< 0.01 < 0.05 > 0.05
Model 3	147.8 (118–190)	91 (60–144)	102.3 (87–121)	< 0.0001	Group 1 vs. 2 Group 1 vs. 3 Group 2 vs. 3	Y Y N	< 0.0001 < 0.0001 > 0.05
Peg transfer: 2D visual modality							
Model 1	234.6 (191–304)	150.7 (76–207)	150.3 (131–191)	< 0.0001	Group 1 vs. 2 Group 1 vs. 3 Group 2 vs. 3	Y Y N	< 0.0001 < 0.0001 > 0.05
Model 2	197.8 (150–279)	174.2 (79–211)	152 (137–164)	0.01	Group 1 vs. 2 Group 1 vs. 3 Group 2 vs. 3	N Y N	> 0.05 < 0.05 > 0.05
Model 3	181.9 (142–231)	110.5 (63–143)	123.4 (118–136)	< 0.0001	Group 1 vs. 2 Group 1 vs. 3 Group 2 vs. 3	Y Y N	< 0.0001 < 0.0001 > 0.05

Table 4. Construct validities: mean total time for performance for models 1–3 in 3D and 2D visual modalities

Exercises	Total time (s), mean (range)			ANOVA *P* value	Multiple comparison Tukey test		
	Group 1: novices (n = 10)	Group 2: intermediates (n = 10)	Group 3: experts (n = 10)		Comparisons	Significant Yes/No	*P* value
Peg transfer: 3D visual modality							
Model 1	189.9 (155–274)	114.2 (60–168)	121.6 (87–150)	0.0005	Group 1 vs. 2 Group 1 vs. 3 Group 2 vs. 3	Y Y N	< 0.05 < 0.01 > 0.05
Model 2	158.4 (131–196)	125.1 (75–161)	132.3 (121–139)	0.01	Group 1 vs. 2 Group 1 vs. 3 Group 2 vs. 3	Y Y N	< 0.01 < 0.01 > 0.05
Model 3	129.2 (118–180)	90.9 (58–114)	101.7 (87.3–117)	< 0.0001	Group 1 vs. 2 Group 1 vs. 3 Group 2 vs. 3	Y Y N	< 0.001 < 0.001 > 0.05
Peg transfer: 2D visual modality							
Model 1	230.9 (191–304)	148.4 (76–207)	147.7 (128–188)	< 0.0002	Group 1 vs. 2 Group 1 vs. 3 Group 2 vs. 3	Y Y N	< 0.05 < 0.0001 > 0.05
Model 2	192.4 (145–230)	169.6 (79–211)	150.8 (142–164)	0.04	Group 1 vs. 2 Group 1 vs. 3 Group 2 vs. 3	N Y N	> 0.05 < 0.05 > 0.05
Model 3	178.6 (142–223)	109.7 (63–142)	121.3 (117–132)	0.0002	Group 1 vs.2 Group 1 vs. 3 Group 2 vs. 3	Y Y N	< 0.05 < 0.001 > 0.05

There was no significant difference in performance time when we compared intermediates with experts for any of the models in either 2D or 3D (Table 4).

Mean total penalties in 3D and 2D visual modalities

Mean total penalties for performance are shown in Table 5. When the groups used the 2D visual system, there were no significant differences between any of the groups with models 1 and 3. With model 2, the mean total penalties score in group was significantly higher than in group 3 ($P < 0.05$); the score for group 2 was significantly higher than that of group 3 ($P < 0.05$).

When the groups used the 3D visual system, there were no statistically significant differences in mean total penalties between the groups with any of the models.

Face validity

All participants answered the six questions on the post-test questionnaires (face validity). Using Likert scales, the participants were asked to rate each model for its features when used with the 2D and 3D visual systems. These results are shown in Table 6 as mean values for all participants.

The novices, intermediates and experts rated each new model higher when visualized in 3D than in 2D, with a score of over 4 out of 5 for all six features. The Student t test was used to assess the difference between two visual modalities. This was statistically significant for five out of six questions ($P < 0.00001$), thus suggesting that the new training models could be appropriate and feasible for learning laparoscopy in a 3D environment at any experience level.

No obvious side effects were reported on the inter-sessional questionnaires while using the 3D visual system.

Discussion

Four basic decision-making approaches for deciding whether a simulation model is valid have been described in recent literature:[22]

(1) Combined verification by development team model users (if the model development team is small)

(2) Model scoring: while conducting research for evaluating various aspects of model use

(3) Independent verification and validation using a third (independent) party

(4) Subjective verification by the model development team (most frequently used)

We have used the first two methods for the purposes of our research: combined verification by the development team

Table 5. Construct validities: mean total penalties for performance for models 1–3 in 3D and 2D visual modalities

Exercises	Total penalties, mean (range)			ANOVA *P* value	Multiple comparison Tukey test		
	Group 1: novices (n = 10)	Group 2: intermediates (n = 10)	Group 3: experts (n = 10)		Comparisons	Significant Yes/No	*P* value
Peg transfer: 3D visual modality							
Model 1	1.8 (0–11)	1.6 (0–5)	0.81 (0–3.3)	>0.05	Group 1 vs. 2	N	>0.05
					Group 1 vs. 3	N	>0.05
					Group 2 vs. 3	N	>0.05
Model 2	0.8 (0–1.6)	0.9 (0–3.3)	1.3 (0–3.3)	>0.05	Group 1 vs. 2	N	>0.05
					Group 1 vs. 3	N	>0.05
					Group 2 vs. 3	N	>0.05
Model 3	2.1 (0–10)	0.8 (0–1.6)	0.6 (0–3.3)	>0.05	Group 1 vs. 2	N	>0.05
					Group 1 vs. 3	N	>0.05
					Group 2 vs. 3	N	>0.05
Peg transfer: 2D visual modality							
Model 1	3.6 (0–13.3)	2.2 (0–5)	2.6 (0–3.3)	>0.05	Group 1 vs. 2	N	>0.05
					Group 1 vs. 3	N	>0.05
					Group 2 vs. 3	N	>0.05
Model 2	5.3 (0–13.3)	4.6 (0–10)	1.3 (0–3.3)	<0.05	Group 1 vs. 2	N	>0.05
					Group 1 vs. 3	Y	<0.05
					Group 2 vs. 3	Y	<0.05
Model 3	3.3 (0–10)	0.6 (0–1.6)	1.9 (0–5)	>0.05	Group 1 vs. 2	N	>0.05
					Group 1 vs. 3	N	>0.05
					Group 2 vs. 3	N	>0.05

Table 6. Face validity for tasks in 3D: mean score for all participants (n = 30)

	Peg transfer	Model 1			Model 2			Model 3		
		3D	2D	*P* value	3D	2D	*P* value	3D	2D	*P* value
Q1	How realistic they look	4.3	3.3	< 0.00001	4.4	3.4	< 0.00001	4.2	3.5	< 0.00001
Q2	How realistic is instrument handling	4.4	3.2	< 0.00001	4.2	3.3	< 0.00001	4.2	3.4	< 0.00001
Q3	Usefulness of hand–eye coordination	4.3	2.8	< 0.00001	4.3	3.6	0.0007	4.5	3.3	< 0.00001
Q4	Ability to perceive depth	4.4	2.7	< 0.00001	4.3	3.2	< 0.00001	4.3	3.3	< 0.00001
Q5	How well the model represents manual skills required for each task	4.4	3.1	< 0.00001	4.2	3.4	< 0.00001	4.3	3.3	< 0.00001
Q6	How well the model tested use of both hands	4.4	4.1	0.06	4.2	4.0	0.07	4.6	4.0	< 0.00001

Ratings on a 1 to 5 Likert scale (1 = very bad, 2 = bad, 3 = neither good nor bad, 4 = good, 5 = very good).

and model users; and model scoring while conducting research for model evaluation.Various validation techniques are described in the literature as listed below.[17] For our research, we have used the first two of the following techniques:

(1) Face validity
(2) Comparison with other models/systems
(3) Animation
(4) Degenerate tests
(5) Event validity
(6) Extreme condition tests
(7) Historical data validation
(8) Historical methods
(9) Internal validity
(10) Multistage validation
(11) Operational graphics
(12) Parameter variability
(13) Predictive validation
(14) Traces
(15) Turing tests

Moulton et al.[23] showed that residents retain and transfer skills better if training is distributed over a number of sessions. It is unclear what main factors are accountable for influencing laparoscopic skill acquisition in novices.[24] There may be several reasons that affect skill acquisition such as 2D versus 3D visual fields, training time, training models, level of supervision, as well as possible innate ability of the surgical trainee.[24] Identifying factors that ease or impede skills acquisition is key to improving the learning curve.[24] Our study addresses one such factor, i.e. model shape. A training model should be developed for a specific purpose (or application) and its validity determined with respect to that purpose.[22] Various simulation models are being used for surgical simulation training. In the development of any new model, validation is essential. There is no set of specific tests that can easily be applied to determine the “correctness” of a model.[22] Studies must be carried out by the model designer and users to assess whether a particular model would serve its purpose.

Validated courses such as the FLS[5] are widely used in practice for skills acquisition and objective assessments.[8] The current FLS peg transfer model has been in use for more than 12 years but is perhaps not the most suitable model because all the posts for the pegs are of the same height and mounted on a flat surface, thus lacking contours and depth. This could possibly hinder skills acquisition and prolong the time needed for training. The peg transfer task is usually the first exercise a novice performs for developing core skills in laparoscopic surgery, i.e. hand–eye coordination, depth perception and bimanual skills.

As newer evidence suggests that simulated skills are transferable to the operating room,[25–28] it is important to maximize learning opportunities[29] in a stress-free environment. Laparoscopic training using 3D imaging systems may ultimately shorten the time required for surgical trainees to reach a basic level of proficiency, enabling maximum benefit during clinical opportunities.[30]

There is emerging evidence in the literature of the superiority of using a 3D visual field in laparoscopic surgery with its improved depth perception.[31–36] Therefore, more complex training models with depth and contours could potentially have an impact on the learning curve and enhance training and skills acquisition in both 2D and 3D visual systems.

A recent study[37] reported a structured training model with a combination of 3D printing and special effects techniques to allow novices to gain valuable experience in surgical techniques without exposing patients to any risk of harm. Another study has shown that mean performance time and total score are significant factors in differentiating novices from intermediates and experts.[38]

In our study, using 2D and 3D visual modalities, we were able to show statistically significant differences in total score and total performance time for model 1 and model 3 when we compared novices with intermediates and experts. Regarding the total score and total performance time for model 2, a statistically significant difference was only noted when novices were compared with experts in 3D. A significant difference was achieved when novices and intermediates were compared with experts for total penalties for performance for model 2 in 2D. Novices, intermediates and experts favoured the 3D visual modality to use the 3D models. Most of the participants found model 2 (two towers) the most difficult to use.

Simulated training is an essential part of laparoscopic training and one would expect that both intermediates and experts would already have acquired core laparoscopic skills and that they would therefore not benefit from further training on acquiring core laparoscopic skills. There was no difference in total score and performance time when we compared intermediates with experts for all models in both 2D and 3D, and thus we would recommend the use of these new models for training novices to improve learning experience and fast track acquisition of core laparoscopic surgical skills.

Limitations and future studies

A power calculation was not performed for this study. Perhaps a larger sample size would be required to confirm our results. That the level of expertise of each participant was not concealed from the assessor could be considered as a limitation of the study; however, we do not feel that this is likely to have affected our results because the performance of the participants was measured objectively. In future studies, the identity of the participant could be concealed from the assessors, for example, by asking the assessor to measure the results from video recordings of the tasks being performed. We plan to undertake a further study to develop a proficiency-based curriculum for the novel 3D peg transfer models. In addition, studies should also be carried out to investigate retention of skills after achieving proficiency using the models.

Conclusions

Laparoscopic training with 3D imaging systems using 3D models may ultimately shorten the time to acquire proficiency in basic laparoscopic skills in surgical trainees. In this study, face validity and construct validity were obtained for three newly developed models for laparoscopic skills training.

We recommend using models 1 and 3 for simulation training in both 2D and 3D visual modalities, and we suggest that this could replace the current relatively flat 2D models for the FLS training course to shorten the learning curve.

Conflict of interest

None declared.

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