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Evaluation of a Virtual Endoscopy Simulator for Training in Gastrointestinal Endoscopy

Background and Study Aims: Skills in gastrointestinal endoscopy mainly depend on experience and practice. Training on endoscopy simulators may decrease the time needed to reach competency in endoscopy. The purpose of the study was to determine whether the GI-Mentor, a virtual reality endoscopy simulator, can distinguish between beginners and experts in endoscopy and to assess whether training improves the performance of beginners.
Methods: A total of 13 beginners and 11 experts (more than 1000 procedures) in gastrointestinal endoscopy were included. The baseline assessment consisted of virtual endoscopies and skill tests. The beginners were randomly allocated to receive training (n = 7) or no training (n = 6). The training group was allowed to practice using the simulator for 2 hours per day. After 3 weeks participants were re-evaluated with two new virtual endoscopy cases and one virtual skill test. Insertion time, correctly identified pathologies, adverse events and skill test performance were recorded.
Results: The baseline assessment revealed significant differences favoring the experts for virtual endoscopies and skill tests. Significant differences in favor of experts were found for successful retroflection during esophagogastroduodenoscopy (EGD) ($P < 0.005$); adverse events during colonoscopy ($P < 0.02$); insertion time ($P < 0.001$); correctly identified pathologies in gastroscopy and colonoscopy ($P < 0.02$); and skill test performance ($P < 0.01$). The final evaluation showed significant differences between training and no-training groups, in favor of the training group, for the number of adverse events during virtual endoscopy ($P < 0.04$), for the insertion time during colonoscopy ($P < 0.03$); and for skill test performance ($P < 0.01$). The training group improved its abilities on the simulator significantly. Differences between experts and the training group were no longer seen.
Conclusion: This virtual endoscopy simulator is capable of identifying differences between beginners and experts in gastrointestinal endoscopy. A 3-week training improves the performance of beginners significantly. This quite fast improvement in endoscopic skills certainly cannot be seen in clinical practice; no conclusions can be made about the impact of virtual simulator training on real-life endoscopy, and this must be evaluated.

Introduction

Skills in gastrointestinal endoscopy mainly depend on experience and practice. Patients who undergo the first endoscopies performed by trainees, are likely to suffer more discomfort and prolonged procedures. Training on endoscopy simulators, the latest generation being electronic virtual reality devices, is said to decrease time to reach competency in endoscopy [1]. The purpose of the study was to determine whether the GI-Mentor (Simbionix, Tel Hashomer, Israel), a personal computer-based simulator with tactile feedback, can distinguish between beginners and experts in gastrointestinal endoscopy. In addition, we examined whether training can improve the performance of beginners.

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Methods

Simulator

Testing and training took place on the GI Mentor, a virtual endoscopy simulator (Figure **1**). Three-dimensional pictures are generated in real time by a computer while the endoscope is moved through the GI-torso. Data about the location and movement of the scope are transmitted via sensors located at the tip and shaft of the endoscope. A force feedback module simulates resistance whenever the virtual GI-tract walls are touched, to provide a realistic "feel" during the procedure. The endoscope used for all procedures is a modified Pentax ECS-3840F; steering and torsion of the endoscope, as well as air inflation and suction, are possible by means of the standard wheels and buttons of the control head of the scope.

Figure 1 Exterior view of the simulator, including the computer and monitor

Figure 2 The "Endobubble" virtual skill test: the on-screen image of a bubble and the needle

The software includes the following features:

1. The "Endobasket" module: the trainee has to navigate with the scope through a virtual pipe, picking up three balls with a virtual biopsy forceps and dropping them into a virtual basket nearby. The time taken and number of correctly placed balls are registered.
2. The "Endobubble" module: the trainee must navigate through virtual pipes as in the previous test. In this test 40 balloons have to be pierced using a virtual injection needle by aiming quickly at them; otherwise the balloons fade away after a certain amount of time. The time taken and number of bubble hits are recorded to measure speed and precision of endoscopic actions (Figure **2**).
3. Virtual endoscopy: the core of the virtual training software in the basic version consists of 10 gastroscopy and 10 colonoscopy cases with various pathologies (Figures **3**, **4**). The characteristics measured are the time to reach either the descending duodenum or the terminal ileum, the number, type and location of the correctly identified pathologies, and adverse events including inappropriate or unsuccessful retroflection, excessive wall pressure or impaired luminal view.

Study Design (Figure 5)

A total of 13 medical residents, forming the beginner group, and 11 experienced endoscopists who had already performed more than 1000 gastroscopy and colonoscopy procedures were included. Beginners were briefly instructed in handling the endoscope. Both groups underwent a baseline assessment of their basic abil-

Figure 3 Virtual endoscopic image of colon cancer

Figure 4 Virtual endoscopic image of grade IV reflux esophagitis

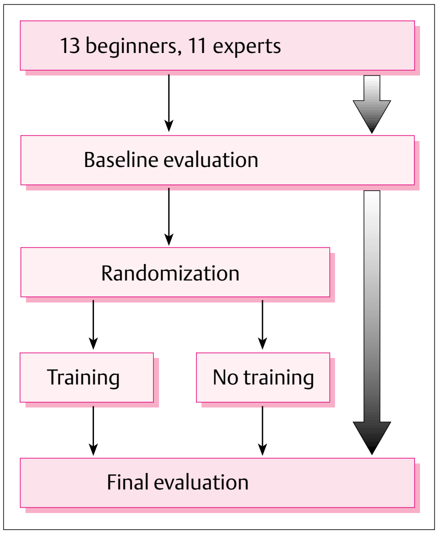

Figure 5 Study design

ities, which included the two virtual skill tests, i.e. "Endobasket" at level 1 (which was repeated three times to assess short-term learning curve), and "Endobubble" at level 2, and two virtual gastroscopies and colonoscopies each. The beginners were then randomly allocated to a training (n = 7) and a no-training (n = 6) group. The training group was allowed to practice on the simulator for 2 hours a day, 5 days per week, using all available features of the simulator. After 3 weeks all participants were re-examined, with the Endobubble virtual skill test at level 2 and one new gastroscopy and colonoscopy case. During the Endobubble test the number of bubble hits was registered, and during the virtual gastroscopy and colonoscopy, the insertion time, correctly identified pathologies, adverse events (inappropriate or unsuccessful retroflection, excessive wall pressure, impaired luminal view) were documented.

Statistics

Continuous data are presented as the median and interquartile range (IQR; from the 25th to the 75th percentile). Percentages were calculated for dichotomous variables. The chi-squared test or, if appropriate, the chi-squared test for trend was used to compare proportions. The Mann–Whitney *U* test or the Kruskal–Wallis test were applied to compare continuous variables between the groups. Friedman tests were used to analyse repetitive measurements. All presented P-values are two-sided: a P-value < 0.05 was considered statistically significant. Calculations were performed using MS Excel for Windows (version 97) and SPSS for Windows (version 10.0).

Results

Baseline Assessment

Endobasket Module

Significant differences between beginners and experts for time taken (minutes:seconds) used were observed in all three consecutive runs (P < 0.005). The median times for the first, second and third run in beginners were 8 : 15 (IQR 5 : 00 to 10 : 38), 5 : 44 (IQR 3 : 30 to 7 : 02) and 3 : 50 (IQR 2 : 35 to 7 : 02), respectively. Beginners showed a significant reduction in the time needed (P = 0.05). The median times for the first, second and third run in the group of experts were 2 : 40 (IQR 2 : 23 to 4 : 34), 2 : 11 (IQR 1 : 13 to 3 : 57) and 1 : 59 (IQR 1 : 24 to 2 : 08), respectively. Experts also showed a significant reduction in the time needed with each subsequent run (P = 0.002).

Endobubble Module

The experts could hit a median of 17 bubbles (IQR 2 to 27), but the accuracy of the beginners was significantly lower, with a median of 3 bubble hits (IQR 0 to 6) (P = 0.009).

Virtual Endoscopy Cases

For the gastroscopy and colonoscopy cases significant differences favoring the experts over the beginners were demonstrated, for the percentage of correctly identified pathologies (73 % vs. 31 % for gastroscopy, 100 % vs. 54 % for colonoscopy cases; P < 0.02); insertion time for gastroscopy (1 : 09 [IQR 1 : 00 to 1 : 34] vs. 2 : 27 [IQR 2 : 16 to 3 : 54]; P < 0.001); and colonoscopy (3 : 40 [IQR 2 : 33 to 4 : 34] vs. 7 : 30 [IQR 5 : 58 to 12 : 22]; P < 0.001); and the number of adverse events during colonoscopy (2 [IQR 1 – 4] vs. 7 [IQR 3 – 8]; P < 0.02); and for successful retroflection during esophagogastroduodenoscopy (EGD) (100 % vs. 46 %, P < 0.005).

Characteristics of the Groups

At the basic assessment, the training and no-training beginner groups did not differ in any tested parameter. Sex, age and computer game experience had no influence on the performance of the contestants within the beginner group. Sex, age, number of endoscopies during the past 10 years and computer game experience within the expert group had no influence on performance.

Final Evaluation

Training vs. No-Training

The final evaluation showed significant differences in favor of the training-group beginners in comparison with the no-training group, for the number of bubble hits (13 [10 – 17] vs. 2 [0 – 3]; P < 0.01) in the Endobubble module; for the insertion time during colonoscopy (P < 0.03); and for the number of adverse events during gastroscopy (0 [0 – 1] vs. 3 [1 – 3]; P < 0.02), and colonoscopy (1 [0 – 2] vs. 2 [2 – 3]; P < 0.04) (Table **1**). As for the time to reach the descending duodenum and the number of correctly identified pathologies, no significant differences were recorded (data not shown).

Training Group vs. Experts

During final evaluation no significant difference was revealed between training group beginners and experts in any tested parameter.

No-Training Group vs. Experts

Differences between beginners without practice and experts were seen for the number of adverse events during gastroscopy (3 [1 – 3] vs. 0 [0 – 1], P < 0.02) and colonoscopy (2 [0 – 3] vs. 0 [0 – 1], P < 0.04), and the number of Endobubble hits (2 [0 – 3] vs. 13 [4 – 33], P < 0.01) (Table **1**).

Training Effects

Significant improvement was seen for the training-group beginners in the number of adverse events both for gastroscopy (baseline) 2 [1 – 4], final 0 [0 – 1]; P < 0.01), and colonoscopy (baseline 7 [4 – 10], final 1 [0 – 2]; P < 0.01), bubble hits (baseline 3 [1 – 7],

Table 1 Results for the "Endobubble" test in beginners ("no-training" and "training" groups) and experts at baseline assessment, and for no-training beginners, trained beginners, and experts at final evaluation. Differences for adverse events during gastroscopy, and adverse events during colonoscopy, between beginners ("no-training" and "training" groups) and experts at baseline evaluation, and between no-training beginners and trained beginners as well as experts at final evaluation

	Beginners (no training)	*Beginners (with training)*	*Experts*	*P-value**
Number of bubble hits, n (IQR)				
Baseline	1 (0 – 6)	3 (1 – 7)	17 (2 – 27)	0.02
Final assessment	2 (0 – 3)	13 (10 – 17)	13 (4 – 33)	0.01
Gastroscopy, number of adverse events, n (IQR)				
Baseline	3 (2 – 4)	2 (1 – 4)	1 (0 – 4)	0.5
Final evaluation	3 (1 – 3)	0 (0 – 1)	0 (0 – 1)	0.02
Colonoscopy, number of adverse events, n (IQR)				
Baseline	5 (1 – 7)	7 (4 – 10)	2 (1 – 4)	0.02
Final evaluation	2 (2 – 3)	1 (0 – 2)	0 (0 – 1)	0.04

IQR, interquartile range; *Kruskal–Wallis test.

final 13 [10 – 17]; P < 0.01), and insertion time both for gastroscopy (P < 0.05) and colonoscopy (P < 0.01). There were no significant differences between baseline and final evaluation for the no-training beginners and the experts.

Discussion

The improvement and standardization of education in endoscopy has become a major issue during the past few years. Problems have been noted primarily in teaching endoscopic novices, as newcomers to gastrointestinal endoscopy need a large number of procedures to gain competency [2 – 4] and suffer from reduced time for individual learning.

For more than 30 years, different types of simulators, including mechanical [5,6], animal [7,8], animal-part [9 – 11], and computer-based models [12], have been developed to teach and learn endoscopic procedures. The goals of simulator-based teaching methods should be the acceleration and improvement of training in endoscopy for beginners; the maintenance of competency when endoscopic procedures are not regularly performed; and the testing and learning of new, mainly interventional methods, before the procedure is performed on the patient.

Computer-based simulator training is simple, nowadays relatively inexpensive, and requires minimal instruction. It allows practice at various skill levels. Most mechanical models lack realism; however, with the most advanced mechanic module, the Tübingen INTERPHANT model [6], interventional procedures can be performed. Living narcotized animals are realistic models, except for minor anatomical differences, but they are expensive, and also involve ethical considerations and the need for special laboratories. In animal-part simulators (EASIE, Endo-Trainer [10,11]), endoscopy is performed in animal organs harvested from slaughterhouses; these are not expensive but need more effort for preparation and cleaning, and are therefore not practicable or accessible for smaller hospitals. They are usually only used in interventional training courses or expert demonstrations; specimens are thrown away afterwards.

Testing with the GI-Mentor can disclose differences between beginners and experts in gastrointestinal endoscopy. A training period of 2 hours per day over 3 weeks can improve the performance of endoscopic beginners. Our results reflected endoscopic experience, and suggest that the simulator is measuring endoscopically relevant parameters. Although the groups were small, differences could be discerned both for the virtual skill tests, which demonstrated the superior hand-eye skills of endoscopic experts and the effect of training in these skills for beginners, and for the virtual endoscopic cases. Thus we identified significant differences between experts and beginners regarding correct identification of pathologies, time needed for endoscopies, occurrence of adverse events during the procedure, and successful retroflection during EGD. Training effects were also demonstrated for these parameters.

However, the 2 hours per day over 3 weeks training led to a substantial reduction of differences between trained beginners and experts, which could certainly not be achieved in real-life endoscopy after such a short period. A reason for that could be the relatively easy handling of the simulator, but also familiarization with the simulator features as a result of intensive training. Even beginners reached the cecum and the terminal ileum regularly in less than 10 minutes in all ten colonoscopy cases. Movements, especially through the colon, are quite easy compared with real life; complex manipulative techniques and loop formations are not simulated, and also intubation and passage through the upper esophageal sphincter, as well as pyloric passage and retroflection for EGD, are not ideally simulated. The virtual skill tests seem to be an appropriate tool for getting used to handling the endoscope and training spatial orientation. Situations in real life, where these applications can be used, are lacking, especially for the Endobubble module (where balloons have to be pierced quickly otherwise they fade away after seconds). Experts and beginners appreciated the realistic three-dimensional movements and gastrointestinal tract graphics. The endoscopy cases surely improve the hand-eye skills [13] but need improvement, probably in measuring the percentage of colonic mucosa visualized in order to train in correct withdrawal techniques, as inadequate proficiency in colonoscopy results in increased adenoma miss rates [14].

Virtual endoscopy simulation could comprise one step in a structured endoscopic training program [15], depending on the level of expertise and the progression of skill in novice endoscopists. With its current hardware and software abilities this virtual simulator can be used for training in basic endoscopic skills; its value for training in interventional procedures, in comparison with special interventional endoscopy simulators [6,10,11], is currently under evaluation.

Virtual simulated endoscopy is a tool which could provide a validated and much needed method for objective assessment of the endoscopist's technical skills [16], which are also the most important factor for patients undergoing endoscopic procedures [17]. In the future we could select people who have more aptitude for this type of work, if even a single simulator test could identify medical students or doctors, who would be talented in endoscopy [18]. Further studies are needed to evaluate the amount of virtual training needed to acquire adequate basic endoscopic skills from simulator training, and whether there is a benefit from regular repetition, or whether the simulator can be used for updating skills after longer periods when endoscopy has not been practised.

Future Perspectives

Considering the rapid progress in software development and consequently in computer-based endoscopy simulation, the incorporation of interventional techniques such as hemostasis, endoscopic retrograde cholangiopancreatography (ERCP), and endoscopic ultrasonography (EUS) will be the next step of simulator development. It will be possible to simulate advanced and demanding after-hours procedures, such as emergency endoscopic hemostasis or colonic decompression, stent implantation and transmural pseudocyst drainage. These situations are rarely available for scheduled training sessions, and would probably be combined with critical incident scenarios such as expulsion of air, unconscious movements, screaming, oversedation, apnea, and cardiac complications.

This study demonstrates that beginners who practise on the virtual simulator then perform better on the virtual simulator. Future studies with the virtual endoscopy simulator will have to test the performance of the trainees in real-life endoscopies. If they perform better than trainees without simulation training, possible effects on performance and safety in real-life endoscopy will need to be investigated in combined studies; conclusions about these issues cannot be drawn from the results of this study. Supervision of the simulator-trained endoscopic novice in real-life endoscopy is mandatory and cannot be replaced by extensive simulator training, as good performance on the simulator might induce a false measure of confidence in the newly acquired abilities. As the measurement of competence and skill in real-life endoscopy is complex, large numbers of trainees are needed to demonstrate the theoretical benefit of this training device.

Conclusion

Testing with the GI-Mentor can distinguish differences between beginners and experts in gastrointestinal endoscopy. A training period of 3 weeks with 2 hours per day improves the performance of beginners on the simulator, which was verified by significant differences in several tested parameters. The value of virtual reality simulator training for accelerating the development of hand-eye skills in endoscopy is obvious; conclusions about its possible effect on real-life endoscopy cannot be made, concluded, and must be evaluated in further studies by measuring the performance of doctors in clinical practice, who have and have not received simulator training.

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