

Virtual reality simulators for gastrointestinal endoscopy training

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Abstract

The use of simulators as educational tools for medical procedures is spreading rapidly and many efforts have been made for their implementation in gastrointestinal endoscopy training. Endoscopy simulation training has been suggested for ascertaining patient safety while positively influencing the trainees' learning curve. Virtual simulators are the most promising tool among all available types of simulators. These integrated modalities offer a human-like endoscopy experience by combining virtual images of the gastrointestinal tract and haptic realism with using a customized endoscope. From their first steps in the 1980s until today, research involving virtual endoscopic simulators can be divided in two categories: investigation of the impact of virtual simulator training in acquiring endoscopy skills and measuring competence. Emphasis should also be given to the financial impact of their implementation in endoscopy, including the cost of these state-of-the-art simulators and the potential economic benefits from

their usage. Advances in technology will contribute to the upgrade of existing models and the development of new ones; while further research should be carried out to discover new fields of application.

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Key words: Virtual endoscopic simulators; GI Mentor; Accutouch endoscopy simulator; Olympus Endo TS-1; Endoscopy training

Core tip: Virtual endoscopic simulators have a great potential in endoscopy training. There are currently two virtual simulators available to purchase as well as others available for non-commercial use. The use of virtual simulators in endoscopy boosts training procedure for upper and lower gastrointestinal endoscopy; the benefits being more prominent in novice trainees. More data are needed to document their position in endoscopic retrograde cholangiopancreatography and endoscopic ultrasound training. Available simulators should not be considered a tool for assessing the skills of endoscopists. The main disadvantage of virtual simulators is their high cost.

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INTRODUCTION

The aim of endoscopy is to achieve the best diagnostic-therapeutic result while minimizing the risks of the patient. Acquiring skills to perform endoscopy needs experience and time and depends on the ability of the trainee,

the feedback given by an experienced supervisor and the method of endoscopy training. Traditionally, novice residents commence their training by performing endoscopies on patients, which might result in prolonged procedure time^[1] and abdominal pain and discomfort for the patient^[2] due to lack of experience. In the era of higher endoscopy costs and increasing demand for advanced invasive procedures that minimize training opportunities^[3], endoscopy simulation has been pointed out as a method of maintaining patient safety through reducing endoscopy errors^[4-6] and achieving better and faster training results. Over the last decades, the use of endoscopy simulators has been spreading rapidly and an increasing number of medical centers in various countries worldwide have already incorporated them in endoscopy training.

ENDOSCOPY SIMULATORS

The first attempts of developing endoscopy simulators were found at the end of the 1960s with the creation of the first mechanical models^[7]. Mechanical simulators have given their position to other more useful and realistic types of simulators, such as live animal models, *ex-vivo* simulators and virtual simulators. Although animal models are considered to offer the most human-like endoscopy experience, they are not widely used due to ethical concerns, the requirement for the presence of experienced staff, unavailability of necessary equipment and cost^[8]. *Ex-vivo* simulators, which engage plastic materials with explanted animal organs are relatively cheap devices useful for scenario based training^[9]. On the other hand, the need for tissue replacement increases preparation time, raises the cost and limits the trainee's access to training sessions^[9]. Virtual (computerized) endoscopy simulators are presented as the most promising tool in endoscopy training. First developed in the 1980s^[10,11], their use is spreading throughout the world and computer evolution aids the rapid improvement of these high-tech modalities. In this editorial, we will focus on virtual simulators, discussing their role in endoscopy training by reviewing the available literature.

VIRTUAL ENDOSCOPY SIMULATORS

Virtual endoscopy simulators are integrated systems that consist of mechanical parts and software. They run a computer program that simulates the procedure of endoscopy using endoscopic images of the gastrointestinal tract while the trainee handles an endoscope attached to a processor that gives a signal to a monitor. The moves of the endoscope interact with the monitor image, offering the user a virtual environment for practicing theoretical and practical knowledge under various conditions^[12]. There are currently two virtual simulators in the market: GI Mentor (Symbionix, Cleveland, United States) and Accutouch Simulator, recently renamed as CAE EndoVR Simulator (CAE Healthcare, Montreal, Quebec, Canada)^[13-15]. There are also simulators available for non-com-



Figure 1 The GI Mentor II simulator (Symbionix, Cleveland, United States), photo provided courtesy of Symbionix.

mercial use, such as the Endo TS-1 simulator (Olympus Keymed, Essex, United Kingdom), the construct validity of which has been tested in several trials.

GI Mentor

Symbionix, a Cleveland, Ohio, United States headquartered company with an Israeli based research unit, produced the virtual simulator that offers the widest variety of tasks available. Suitable for upper and lower endoscopy training, GI Mentor provides a large library of modules from basic endoscopic skills and simple clinical procedures to complicated situations such as emergency gastric bleeding. There are also modules for endoscopic ultrasound (EUS) and endoscopic retrograde cholangiopancreatography (ERCP) training. The simulation program includes features like a pain indicator and scope locator and trainees also have the opportunity to practice on virtual patient cases based on actual medical data^[16] (Figure 1).

Accutouch endoscopy simulator

Although the company recently changed the name of the simulator, we will keep the old name throughout the manuscript because it appears as “Accutouch” in the available literature. The redesigned in 2012 simulator of CAE Healthcare (Canada) provides the user with a new, more realistic haptic sense of endoscopy. Modules of esophagogastroduodenoscopy (EGD), colonoscopy and endoscopic retrograde cholangiopancreatography (ERCP) are available and the trainee can also acquire skills in polypectomy, biopsy and hemostasis^[17]. CAE's simulator offers a complete endoscopy experience by combining the endoscopy procedure with the background of a virtual patient. Endoscopy starts with the patient's history and various parameters change during endoscopy, such as vital signs and patient response to pain and discomfort. The trainee is also assigned to achieve the ideal virtual sedation without reducing the patient's oxygen saturation^[18] (Figure 2).

Olympus colonoscopy simulator (Endo TS-1)

The Endo TS-1 (Olympus Keymed, United Kingdom) is



Figure 2 The CAE EndoVR (previously Accutouch) simulator (CAE Healthcare, Montreal, Canada), © 2013 CAE. Photo provided courtesy of CAE Healthcare.

a second generation virtual reality simulator that provides real-time movements of the colonoscope^[19]. An Olympus CF180L endoscope is customized for the needs of the simulator and gives the user a realistic colonoscopy-like haptic sense by simulating the moves of the endoscope and the patient^[20]. Olympus' Scope Guide that provides a 3-dimensional image of the position and shape of the endoscope within the colon was used as a pattern for Endo TS-1 and the luminal view is accompanied by a training tutorial^[20]. The software is currently being updated and more complex procedures, like polypectomy, will be added^[20].

USING VIRTUAL ENDOSCOPY SIMULATORS

From the first efforts of creating virtual endoscopy simulators to now, the positioning of these modalities regarding endoscopy training is still questioned. Numerous studies tried to investigate the improvement of endoscopy skills of trainees with various experience in endoscopy after receiving sessions of virtual endoscopy training. Other studies focused on using virtual simulators for the evaluation of acquired skills. Undoubtedly, use expansion of these high tech computer based machines depends on giving answers to these important issues.

Training

The significant acceleration of training procedure to the threshold that trainees are considered to have acquired sufficient skill is the most important condition for the positive validation of a simulator^[21,22]. Although modern virtual endoscopy simulators offer a large variety of modules, trials reviewed herein examine only the effect of virtual endoscopic training in upper gastrointestinal endoscopy, colonoscopy and flexible sigmoidoscopy. The results of the major trials that examined the influence of virtual endoscopy simulators in gastrointestinal endoscopy training of novice trainees are shown in Table 1.

Regarding upper gastrointestinal endoscopy, training with the GI Mentor simulator in combination with a

mechanical and an *ex-vivo* simulator seems to positively influence the learning curve of novice endoscopists when combined with clinical training, while independent simulator training appears to be insufficient^[23]. Data reviewed from a Medical University of Vienna study indicate that trainees who underwent training sessions with a virtual endoscopy simulator before conventional training benefited in their first ten endoscopies on patients regarding procedure completion time and technical accuracy (as rated by experts) in comparison to their non-simulator trained fellows. A statistically significant difference in gastroscopy duration was still observable after 60 endoscopic examinations^[24]. On the other hand, missed diagnosis of pathological findings, evaluated by blinded experts, was not significantly different between the two groups^[24].

Three randomized, blinded, controlled trials have demonstrated the positive impact of three different virtual endoscopy simulators on the performance of novice colonoscopists. The first study, performed in Karolinska Hospital, Sweden, proved a significant increase of colonoscopy completion rate and reduction of both procedure time and patient discomfort in trainees who had already achieved a predetermined performance in the Accutouch simulator compared with controls^[25]. In the second multicenter trial, the influence of GI Mentor simulator pre-training was investigated. The results showed that the pre-trained residents achieved higher competency scores than their control trainees during their first 100 cases; the difference in performance was even more prominent in their first 80 colonoscopies^[26]. A third multinational European trial proved that novice trainees trained with the Olympus virtual simulator received similar rates by blinded experts in three live colonoscopy cases in comparison to others who underwent traditional training only. However, they achieved better results in simulator metrics in three virtual simulator cases than their fellows trained on patients^[27].

Furthermore, one study demonstrated that skills acquired after sessions of colonoscopy training with virtual endoscopy simulators seem to be maintained for several months after the end of training^[28]. The presence of a supervisor also boosts the training procedure as trainees complete the colonoscopy simulation and reach simulator proficiency levels faster than individual training^[29]. Finally, intensive hands-on colonoscopy courses using computer simulator and live case teaching positively influence trainees' skills measured by a computer simulator and by a clinical index, while results are maintained during a 9 mo follow-up period^[30].

The use of sigmoidoscopy virtual simulators was investigated in two trials. The results of a prospective randomized trial were not promising since trainees who were trained using virtual endoscopy simulators exclusively experienced more technical difficulties regarding initial endoscope insertion, negotiation of the rectosigmoid junction and ability to perform retroflexion, while their procedure completion rate was significantly lower than that of controls^[3]. Another study demonstrated that a 3 h

Table 1 Evaluation of virtual simulators for the training of novice endoscopists

Ref.	Simulator	Procedure	Groups	Outcome measurement	Result
Ende <i>et al</i> ^[23]	GI Mentor (plus a mechanical and an <i>ex-vivo</i> simulator)	Gastroscopy	Clinical plus simulator training Clinical training only Simulator training only	Skills evaluation score Time (s) to pass pylorus	Median score: 7 vs 6 vs 5 (P = NS) 183 ± 65 vs 207 ± 61 vs 247 ± 66 (P = NS)
Ferlitsch <i>et al</i> ^[24]	GI Mentor	Gastroscopy	Simulator training before conventional training Conventional training	Time (s) to reach duodenum Percentage of unaided examinations (after 10 endoscopies)	239 vs 310 (P < 0.000) 85% vs 72% (P < 0.01)
Ahlberg <i>et al</i> ^[25]	Accutouch simulator	Colonoscopy	Simulator group Control group	Cecum reached during the first 10 colonoscopies Time (min) to reach cecum Patient discomfort (estimated probability in group 2)	52% vs 19% (P = 0.0011) 30 vs 40 (P = 0.037) 2.27 (95%CI: 1.14-4.76)
Cohen <i>et al</i> ^[26]	GI Mentor	Colonoscopy	Simulator group Control group	Competency after 100 cases Number of cases for reaching competency	Higher in group 1 (P < 0.0001) 160 in both groups (P = NS)
Haycock <i>et al</i> ^[27]	Olympus simulator	Colonoscopy	Simulator group On patient trained group	Live colonoscopy cases Completion rates Time taken Virtual simulator cases Cecum intubation Time (s) to cecum intubation	11% vs 7% (P = NS) 20 min vs 20 min (P = NS) 95% vs 70% (P < 0.01) 407 vs 743 (P < 0.01)
Gerson <i>et al</i> ^[3]	Accutouch simulator	Sigmoidoscopy	Virtual simulator training (without on-patient training) On patient training group	Time (min) to complete the live case Live cases that trainees completed independently	24 vs 24 (P = NS) 29% vs 72% (P < 0.001)
Sedlack <i>et al</i> ^[31]	Accutouch simulator	Sigmoidoscopy	Simulator group Control group	Patient discomfort score (1-10) Competence score to perform endoscopy independently (1-10)	1.3 vs 4 (P < 0.01) 2.8 vs 8 (P = NS)

NS: Not significant.

simulator pre-training course did not show a measurable effect in the graded skills of identification of pathology and safe scope insertion of novice trainees performing sigmoidoscopy. However, the patients experienced less discomfort^[31].

There is limited information regarding the usefulness of virtual simulators in ERCP training. In two United States surveys in which ERCP virtual endoscopy simulators were evaluated compared to other modes (a mechanical simulator in the first study, an *ex-vivo* simulator and a live porcine model in the second), virtual simulators received lower scores in terms of realism and usefulness but they were ranked as more user friendly^[32,33]. In another United States study, novice and expert endoscopists positively evaluated graphics and haptic realism of the ERCP module of GI Mentor and the vast majority of them claimed that it should be considered a useful ERCP training tool^[34].

Finally, there are no data about GI Mentor's EUS mode contribution in trainees' learning curve. Kefalides *et al*^[35] tested this EUS simulator mode and claimed that improvement is needed before being used as training tool. At the same time, eight EUS experts gave EUS Mentor mode the highest score among a mechanical simulator, an *ex-vivo* simulator and a live pig model in terms of usefulness and realism but expressed a negative view about the virtual simulator's EUS-FNA training mode^[36].

Evaluation of endoscopic skills

The success of endoscopy depends on a number of fac-

tors, including among others, the endoscopist's technique, patient's condition and tolerance and the quality of equipment. As a result, it is difficult to assess endoscopic skills and there is no widely accepted scale for measuring competence. For a reliable evaluation of the training process, virtual endoscopy simulators must correlate simulator based benchmarks with clinical skills^[37] and simulators' competitiveness scores with accepted clinical metrics^[38].

The validation of the Olympus virtual simulator to evaluate colonoscopy skills has been tested in two different trials demonstrating promising results. In one trial that included participants with no endoscopy experience, trainees with median experience and experts showed a significant reduction of simulator procedure time and better scores in parameters measuring technique, like the number and size of passed sigmoid loops and use of variable stiffness function that depended on user's experience^[20]. Another trial that included novices and experts demonstrated that experts achieved higher scores in colonoscopy competence measured by an Olympus simulator scale but the difference was not statistically significant^[39].

Surveys involving GI Mentor as a skills assessment tool have shown contradictory results. Two studies, both dividing participants into novices, medium-experienced and expert endoscopists, have shown significant differences between novices and the other groups regarding virtual colonoscopy completion time and other parameters such as the percentage of lumen surface examined. Differences though were less prominent after the users had reached certain endoscopic experience^[40,41]. A third

trial demonstrated that GI Mentor colonoscopy simulator modules with a higher level of complexity were more suitable to distinguish endoscopists with different experience^[42]. On the other hand two other surveys raised doubts about the reliability of GI Mentor to evaluate colonoscopy skills. A University of Pennsylvania, United States trial showed that the virtual simulator was unable to differentiate between novices and experts, not only in colonoscopy modules but also in upper gastrointestinal endoscopy modules^[43], while a Cleveland, United States study displayed a wide range of scores in virtual colonoscopies performed by experts, claiming that an upgrade is needed for simulators to be considered accurate tools for measuring endoscopic skills^[44].

The ability of the GI Mentor ERCP module to discriminate between novices and experts was tested in a US study. The combination of results in two simulated cases proved a statistically significant difference between the two groups but the study sample size was small and only one institution was involved^[34].

The construct validity of the Accutouch sigmoidoscopy simulator has been tested in two trials. The simulator discriminated between groups with different sigmoidoscopy experience but results from the simulator metrics were not statistically significant in one of the two studies where experts and senior trainees were compared^[45,46].

Finally, an attempt for creating a universal scale for measuring competence using virtual simulators was made in a multicenter Canadian trial. The researchers developed the “Global Assessment of Gastrointestinal Endoscopic Skills” for upper gastrointestinal endoscopy and colonoscopy, demonstrating a statistically significant difference between the scores of novices and experts^[47].

FINANCIAL IMPACT

The two virtual endoscopy simulators currently available in the market are quite expensive. The cost of GI Mentor starts from \$64500 (gastroscopy and colonoscopy modes) but the purchase of more complicated modules, such as those available for ERCP and EUS training, can raise the cost up to \$114000^[9]. As far as the Accutouch simulator is concerned, upper and lower gastrointestinal endoscopy packages can be purchased separately. The cost of the upper gastrointestinal endoscopy package is \$46750 (bleeding mode upgrade adds \$19000 to the cost), while the lower gastrointestinal endoscopy package is available at \$74750. The addition of advanced modules, like the ERCP module and colonoscopy biopsy module, increases the cost from \$7175-8650 for each separate purchase^[9]. This high cost is the main reason that precludes the widespread of these modalities in countries where the total number of endoscopy trainees does not justify the cost or current fiscal austerity measures impose tremendous cut in state public health spending^[48].

Their main financial advantage in comparison to other types of simulators, like *ex-vivo* and animal models, is that after installation, the expenses are minimized. The presence of a supervisor in a virtual endoscopy training

procedure is not cost effective according to a University of Alabama study^[49]. The concept of mobile virtual endoscopy simulators, being shared by more than one institutions, proved successful^[50] and collaborative use may reduce the cost of their use in the future. Use of virtual endoscopy simulators though seems to also have a positive influence in health economics by reducing procedure time related to trainee involvement in endoscopy^[11] and by limiting potential procedural complications and incorrect diagnosis^[51]. Further research should be carried out in order to quantify the profit from their use.

CONCLUSION

Virtual endoscopy simulators use at the early stages of endoscopy training has considerable impact in the performance of novice endoscopists, not only in gastroscopy but also in colonoscopy. The benefit of their use for trainees who have acquired certain experience appears to be limited, while more data is needed to document their position in ERCP and EUS training. Despite the efforts for developing virtual simulators as tools for measuring endoscopic skills, the available modalities should not be considered as an objective means for validating the competitiveness of endoscopists. The main disadvantage of these computer-based simulators is their notably high price. The concept of mobile simulators and the purchase of basic modules of virtual simulators could be a solution for reducing cost. Rapid improvement in software and hardware technology promises even more realistic simulators and replacement of the first stages of conventional training with simulator training at a reasonable and affordable cost is the developers' challenge for the future.

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