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SURGICAL ENDOSCOPY
and Other Interventional Techniques

Virtual reality surgical laparoscopic simulators

How to choose

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In the past 10 years, minimal access surgery (MAS) has replaced open surgery for a variety of procedures. In general surgery, procedures such as cholecystectomy, antireflux surgery, bariatric surgery, colon surgery, and knee and shoulder surgery are performed laparoscopically, and laparoscopy is used increasingly for surgical procedures fields of gynecology, cardiac surgery, and urology [14]. MAS imposes specific strains on the surgeon requiring specific psychomotor abilities and skills due to the videoscopic surgical interface. Conventional teaching methods for open surgery, such as the classical apprenticeship with hands-on theater experience, do not emphasize the acquisition of such skills. Furthermore, when performing endoscopic surgery, surgeons in training cannot easily mimic their mentor's actions or maneuvers without first manipulating the laparoscopic instruments in an initially disorientating, two-dimensional environment [6].

Due to the nature of laparoscopy, it will likely benefit from developments in virtual reality (VR) technology. In fact, elaborating on the successful paradigm of flight-simulator training for pilots, the potential of VR applications for laparoscopic surgical skills training was proposed almost a decade ago [7]. Recent advances in computer technology, combined with the consensus about the need for shortening learning curves in surgery in a nonpatient but equally informative teaching settings, have led to the development of laparoscopic VR simulators. Evidence is accumulating that such simulators appear to be valid instruments in the acquisition of surgical laparoscopic skill [2–5, 8–13].

Because there are many "players" in the field of medical VR simulation, and because developments are evolving fast, it is quite difficult and confusing for the potential consumer to be informed about what is on the market and to how make a proper choice among available simulators. In fact, there are several models, some with identical hardware but all featuring different software. Basic and more advanced laparoscopic simulations are available, each with different features, and sometimes different intentions. This review provides an overview of the main simulators available, highlights assets and shortcomings, clarifies underlying similarities, and notes their differences. Not all companies offer both software and hardware simulation environments, and partnerships between several companies have been formed. An attempt has been made to feature the most important, most promising, and/or the "leading" companies in the area of laparoscopic VR simulation.

Care was taken to ensure that information is up-to-date and correct. However, we had to rely largely on information provided by the participating companies. The importance of correct, realistic, and unbiased information was stressed. We cannot fully exclude or be held responsible for errors resulting from faulty information.

Methods

Eight companies, all renown firms in the field of hardware and/or software laparoscopic virtual reality system development, were asked to participate in the study. All companies were sent a similar, open-ended questionnaire asking for a description of their VR simulator and its features, modules, and properties for assessment. Furthermore, primary user target groups were defined as well as the specific simulators' most important aspects, shortcomings, and technological specifications.

Results

Table 1 gives a comprehensive overview of the major companies in the field of laparoscopic surgical simulation and their simulators. Some companies offer complete simulation solutions. Others emphasize either software or hardware development and are often linked in mutual partnerships. Most companies indicate their

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Table 1. Overview of simulators

	Company											
	Reachin			Mentice			Surgical Science					
	RLT		SimSurgery	Procedicus MIST		Select-IT VEST	LapSim		Immersion		Simbionix	Xitact
	B	BC	VR Anastomosis Trainer	"Classic"	Procedicus	VSOne	Basic skills	Dissection	VLI	LSW	LapMentor	LS500
Basic skills									NA	NA		
Navigation/ coordination	●	●	○	●	●	●	●	●			●	○
Touching	●	●	●	●	●	●	●	●			●	●
Grasping	●	●	Needle	●	●	●	●	●			●	●
Stretching/traction	●	●	○	●	●	●	●	●			●	●
Translocation	●	●	Needle	●	●	●	●	●			●	○
Others	—	Forceback	—	—	—	—	—	—			—	—
Advanced skills									NA	NA		
Clip applying	●	●	○	○	●	●	●	●			●	●
Transsection/cutting	●	●	○	○	●	●	●	●			●	●
Dissection	●	●	○	○	○	●	○	●			●	●
Diathermia	●	●	○	○	●	●	○	●			●	●
Suturing	○	○	●	○	●	●	●	●			○	○
Knot tying	○	○	●	○	●	●	●	●			○	○
Cholangiography	○	●	○	○	○	*	○	○			●	○
Others	—	—	—	—	—	—	Ultrasound Scissors Rinse suction	Ultrasound Scissors Rinse suction			—	—
Modules	B	BC	SimLap SimCor SimPlanner	MIST Core skills 1 & 2	KSA MIST M-suture M-arthro	GYN or CHO CBT BTT SPT	Basic Skills	Dissection	Other simulators AccuTouch Endovascular & Endoscopy CathSim Vascular (own hardware and software)		Basic tasks CBT Lap. Chol. Full procedures	Lap. Chol. Clip–cut Dissection
Force feedback	●	●	○	○	[a]	●	[a]	[a]	○	●	●	●
Playback function	○	○	○	●	●	[a]	○	●	NA	NA	●	●
Video	○	●	●	●	●	●	○	○	NA	NA	○	●
Assessment	●	●	●	●	●	●	●	●	NA	NA	●	●
Validation	[b]	[b]	○	●	[b]	○	[b]	○	NA	NA	[b]	●
Cost (euros)	B, 58,900; BC, 72,800		No price indication	From 16,000	From 25,000	70,000/ 112,500	39,000	54,000 (including Basic Skills)	6,000	28,000	90,000	110,000

○, not present; ●, present; NA, not applicable
[a] Optional
[b] In preparation or studies not available through PubMed

intended primary user group to be surgical trainees, specifically physicians (residents) in preparation for their first live MIS operation. Some companies stress the importance of their simulator as an objective assessment tool.

For each simulator, the basic and advanced training modules available are listed in Table 1 as well as more simulator-specific modules. The presence or absence of force feedback is noted, reflecting the important asset of haptic sensation. In some simulators, force feedback is optional. The presence of a performance playback possibility is noted as well as the presence or absence of "live" surgical or instructional video clips of the procedure. All simulators feature some form of assessment, which is explained in the specific sections in more detail. Finally, Table 1 notes which simulators are and which are not yet validated.

Reachin

Reachin Technologies AB was founded in 1997 as a result of a collaboration between research institutes in Australia, Singapore, and Sweden. Reachin's Laparoscopic Trainer (RLT) is their simulator. Two versions are available: the Reachin Laparoscopic Trainer Basic (RLT-B) for basic skills training and the Reachin Laparoscopic Trainer Basic and Cholecystectomy (RLT-BC) for basic skills training and laparoscopic cholecystectomy.

Features

The RLT-BC module follows a four-step system. Tasks start with an instruction video, followed by a playback lesson commenting on the video. The third step, called Forceback™, leads the trainee through the procedure. The trainee merely holds the instruments, following the autonomic movements of the instruments as previously recorded through the performance of an expert laparoscopic surgeon. It is possible to incorporate the movements of an expert laparoscopic surgeon of one's own hospital. Finally, the trainee has a free-format session, making his or her own movements. Six complementary video instruction lessons are available for the RTL-BC.

Assessment

Movement patterns are recorded and, thus, it is possible to present performance data. Touch-sensitivity thresholds can be set according to the Administrator's preferences. Bilateral movement patterns can be displayed and compared to the "ideal" route. Data on acceleration of movement and performance errors, such as faulty touch of tissue and incorrect use of diathermia, are available. The Lesson Management Environment is Reachin's Web-interfaced tutorial management system offering a variety of possibilities to the administrator (i.e., the creation of classes, designing courses, remote tutoring, and viewing of results from any remote location). Raw data are stored in XML format for exchangeability and calculation purposes.

Most important aspects

The Forceback feature is unique. The BC module instructs the student gradually through a procedure. The Web-based Lesson Management System offers easy remote control.

Shortcomings

The system cannot perform a full laparoscopic procedure from start to finish. There is no playback possibility of the performance of the participant. Validation studies are ongoing.

SimSurgery

SimSurgery AS was established in 1999 to develop medical simulation software and solutions for virtual training and robotic surgery. Its software has been developed by specialists in mathematics in collaboration with the Norwegian National Hospital. SimSurgery developed the VR anastomosis trainer. Basically, their software can be adapted to any surgical simulator or any other system requiring real-time three-dimensional (3D) capacity.

Features

The VR anastomosis trainer trains laparoscopic continuous suturing. A module has been developed to perform suturing for connecting a simulated artery onto a coronary artery on a beating heart (SimCor module). A surgical planning module (SimPlanner) teaches the trainee the optimal configuration of the surgical robot system and port placements. The simulated robot and operating room scenes can be merged with patient 3D data from CT and MRI scans. Knot-tying is available.

Assessment

Time to complete the procedure is recorded as part of the simulation. The placement of stitches and needle/instrument trajectories are part of the evaluation database.

Most important aspects

SimSurgery SIM3DM is a major software developer, licensing its products to Zeus' robotic system (Computer Motion), the Procedicus platform (Mentice), and Immersion's VLI. SimSurgery's Web site is informative, with links to videos and images of the various systems, articles in the literature, and partners.

Shortcomings

The anastomosis trainer needs a separate hardware platform to run on. Thus, the software itself cannot mimic force-feedback.

Mentice

Mentice, a Sweden-based corporation, develops medical simulation software and systems. The Procedicus, featuring Minimally Invasive Surgical Trainer-Virtual Reality (MIST-VR) Core Skills 1 & 2, is suitor to the "classical" MIST-VR surgical simulator launched in the mid-1990s. The Key Surgical Activities (KSA) module and MIST suture module, developed by SimSurgery, and other modules can be incorporated in the Procedicus platform.

Features

Procedicus is a modular simulation environment. From a functional stand-point, it can be divided into two major groups: the Procedicus MIST "classic" for basic skill acquisition and the Procedicus simulation platform. This platform was originally developed for the virtual arthroscopy shoulder and knee simulation; later, the laparoscopic KSA module was implemented. Three MIST modules are available: the MIST Core Skills 1 & 2 for basic psychomotor training and the MIST suturing module for training of needle handling, suturing, and (forthcoming) knot tying. The original MIST system does not provide force feedback (because it uses Immersion's VLI) but has a "color code" for guidance. When running MIST on Procedicus, force feedback is optional. Procedicus has configurable levels of skill/task difficulty for each module. The Core Skills modules covers six basic exercises. The Procedicus KSA module was designed for more advanced laparoscopic training, focusing on procedures such as scope and instrument navigation, pick and place, pick and pass, cutting, suturing, needle passing, and the use of diathermy in a VR abdominal environment. The Procedicus environment can incorporate training modules in arthroscopy, interventional cardiology, and endovascular surgery.

Assessment

A database contains records of students across trained modules. It keeps track and organizes classes and curricula. The system recognizes where the trainee has left off and will move on to the next scenario, with feedback on performance and a posttest at every level. The instructor can follow and comment on the student's progress through the Internet. There is a performance analysis and report tool set, and data can be imported exported. For the Core Skills module 1 & 2, performance is measured by time, number of errors, and tool efficiency.

Most important aspects

Various modules for the Procedicus MIST-VR system are available. In addition to the KSA module, other minimally invasive simulations in arthroscopy, urology, gynecology, interventional cardiology, and radiology are available. The MIST system is the most extensively validated VR system in surgical VR training.

Shortcomings

Force feedback with the Procedicus system is optional, based on the Immersion hardware that is used. Mentice acknowledges that there are still limits to the level of its haptic realism.

Select-IT VEST systems

Select-IT VEST Systems AG was founded in 2000 by a team of experts in endoscopy, surgery, VR, mechatronics, marketing, and sales. Their simulator is the Virtual Endoscopic Surgery Training (VEST) system. Two applications of the VEST system are available: the VSOne Cho trains laparoscopic cholecystectomy, and the VSOne Gyn trains laparoscopic gynecology.

Features

Both VSOne applications have a basic and more advanced set of surgical training tasks. It is a network-compatible assessment platform. VSOne offers different training programs. Both VSOne Cho and Gyn have peer-reviewed computer-based training (CBT), a basic task training set (BTT), surgical procedure training (SPT), and either a cholecystectomy or a gynecology (laparoscopic sterilization/ovary manipulation) simulation. BTT familiarizes a trainee with the system and trains basic laparoscopic tasks, such as camera handling, navigation, and dexterity training. It focuses on manipulation and coordination skills with endoscopic camera and tools in a nonanatomic, game of skill-like parcourse. SPT modules train more specific surgery procedures, such as suturing, dissection, knot tying, clipping, and cutting. The VSOne Cho and Gyn modules are specific surgical applications. Force feedback is coupled to all procedures.

Assessment

Optional to the system is an authoring toolkit, that allows the user/trainer to design and implement customized procedures and trainings. Performance scoring depends on the kind of exercise. In general, the parameters time and errors are used to construct performance diagrams and show task history, and precision of performed task and economy of operation are measured as path length if applicable. Errors are defined depending on the procedure. In general, errors result from touch in restricted areas or clipping/cutting outside feasible regions, touch with forces higher than predefined values (values depend on the procedure), and incorrect use of coagulation. Data are stored in a database for postprocessing, for example, by Microsoft Excel.

Most important aspects

The VSOne is an open system. The included CBT with Internet access allows for theoretical training in surgery with the possibility of earning CME credit points. The authoring tool makes VSOne a platform for designing and implementing individual trainings.

Shortcomings

VSOne is missing force feedback in the grip. This problem is recognized and is currently the focus of research and development. The system is not fully validated; studies are ongoing.

Surgical Science

Surgical Science AB was founded in 1999 and is based in Sweden. Its LapSim is a simulator featuring different training modules for training of minimally invasive surgical skills. The simulation programs are LapSim Basic Skills and LapSim Dissection.

Features

LapSim Basic Skills 2.0 offers a set of nine training modules. Practice sessions may vary in graphic complexity as well as level of difficulty, and preferences can be set individually. LapSim Dissection aims at practicing both blunt and sharp dissection in the area of the hepatoduodenal ligament. Anatomical variations are present. For both programs, curricula can be created or modified by the teacher to fit a trainee's specific needs or the training requirements. In Basic Skills, nine training modules are featured, ranging from navigation to more advanced skills such as coordination, grasping, cutting, clip applying and suturing, in which the task is to make a stitch and a double knot. It also features a game-like module integrating different skills at different levels, coupled to a scoring system. In Dissection, different anatomical variations are available. Parameters to be set are lens angle, tissue properties, tissue environment, object size and numbers, object movements, time limits, and handedness. A variety of instruments can be used. Exercises in both simulation programs can be performed at different levels of difficulty. Force feedback is optional. LapSim is a network-compatible device.

Assessment

In the assessment mode, curricula can be designed and data assessed. Parameters such as time, errors, tissue tension and damage, and movement patterns and trajectories are recorded. Depending on the module, parameters such as bleeding and number of clips used can be measured as well. Results are presented in graphical figures and illustrations. Examinations are provided to validate student's progress, and requirements for passing an examination can be set by the administrator. Data can be exported.

Most important aspects

The system has a high degree of realism with regard to graphics and tissue–instrument interaction. Different anatomical settings are available in the dissection program. The system is flexible and based on a platform/module principle. There is a simple network connection.

Shortcomings

There are no complete surgical procedures available. Validation of the system is limited but ongoing. Force feedback is optional.

Immersion

Immersion Corporation was founded in 1993. The company develops hardware and software systems for surgical simulation settings. For laparoscopic simulation, the Virtual Laparoscopic Interface (VLI) and the Laparoscopic Surgical Workstation (LSW) were designed. Both VLI and LSW are systems enabling developers, researchers, and educators to develop specific software for simulating laparoscopic abdominal procedures. The VLI is a system for tracking instrument motions associated with minimally invasive surgical procedures. The LSW is specifically designed for acceleration of learning curves in minimal access surgery, integrating force feedback. The simulators are licensed to different manufacturers/developers, integrating Immersion's technology in their specific medical simulation devices. Surgical Science uses the VLI as the hardware platform for its LapSim basic skills, as does Mentice in its classic MIST environment. The LSW is used by Reachin, Surgical Science, and Mentice.

Features

VLI offers a method for monitoring pitch-and-jaw motions of laparoscopic instruments. It tracks the motion of a pair of surgical instruments through a 3D workspace. Tools have five degrees of freedom, encompassing the motion range of most laparoscopic procedures. There is a near real-time representation of the movement of the hands to the image on screen. It allows users to become comfortable with the remote manipulation of surgical instruments, accelerating the experience curve for laparoscopic procedures for both physicians and students. LSW offers basically the same features but has TouchSense technology and different sets of handles. No specific surgical modules are supplied with the simulators. However, a software development kit is provided with the both systems.

Simbionix

Simbionix is headquartered in Cleveland, Ohio, and has a subsidiary in Israel. The company has been developing and producing training simulators for minimally invasive surgery since 1997. The LapMentor is their laparoscopic surgical simulation platform.

Features

The LapMentor allows for practicing of basic laparoscopic skills using the Basic Task Modules (BTM), as well as for more complex skills mimicking surgical laparoscopic procedures. In BMT, a variety of basic skills in a nonanatomic setting can be practiced, such as camera navigation at 0° or 30°, instrument navigation, object manipulation, and clipping and cutting. More complex skills, including virtual patient cases, allow practice of realistic laparoscopic procedures, such as laparoscopic cholecystectomy. In the Cholecystectomy Basic Tasks (CBT), a variety of didactic basic tasks in an anatomical setting, such as cystic artery and duct exposure, cannulation tasks, and a tutorial cholangiogram can be explored. A virtual instructor guides the trainee and gives intrasimulative feedback. Actual setup of operative port placement can be mimicked and changed during operation.

Assessment

The trainee receives immediate feedback from the virtual instructor. Different training curricula can be set up. Quantative parameters of performance vary over task and procedure. Among these are total time, efficiency rate for task, safety parameters (percentage safe clipping, percentage safe cutting, minimal length in distances between clips, amount of energy used for diathermia, safe cautery, percentage of thorough dissection, speed, and navigation). Didactic parameters such as decision-making options (“convert to open” option and the reason to convert) are included. Scores reflect task time, speed, and navigation parameters as well as accomplishment of task. The score for the virtual patient cases is based on an equation reflecting all the quantitative parameters and can be fine-tuned according to the training methods used by the administrator. The export data feature enables the administrator to transfer information.

Most important aspects

The system has high-quality anatomical visual representation, featuring patient cases using CT/MRI images from real patients. Complete and continuous laparoscopic procedures are represented. The physical insertion of the laparoscopic instruments can be mimicked using a number of possible ports. Furthermore, Simbionix is known for having experience with other simulators in the medical field (gasteroscopy, urology, percutaneous, and endoscopic ultrasound).

Shortcomings

The ability to provide realistic tactile sensation in LapMentor is limited. Validation of the system is preliminary.

Xitact

Xitact SA was founded in 2000 in Morges, Switzerland. Its product was developed by independent expert laparoscopic surgeons and technical hardware and software engineers. Its product is the Xitact LS500 laparoscopy trainer platform. The Xitact LS500 is a laparoscopy simulator providing a modular training environment for the education and assessment of laparoscopic procedural surgical skill.

Features

The Xitact LS500 features two simulation environments, the clip–cut curriculum and the peritoneal dissection curriculum in the environment of the laparoscopic cholecystectomy. It combines proprietary force feedback technology with real-time deformation of organs within the simulation environment. Both the clip–cut and the dissection curriculum provide a multidisciplinary stepwise training environment, including elements such as surgical video clips with voice-over, phased simulation instructions, a library of performance errors, simulation playback, and assessment recordings. Two performance modes are incorporated—a free-format mode and a guided mode with specific instructions for gradually increasing the level of skill needed to perform the complete exercise. Feedback through a performance report is presented at the end of the exercise.

Assessment

Administrators can build “classes” and specify “curricula” and thus are able to create and monitor progress on different surgical curricula for individual user accounts. A performance report is available the shows validated general sum score incorporating performance time and the number and nature of errors (clips used, correct distances and placement of clips, cutting errors, bleeding, and leakage). Tool trajectories are also recorded. Improvement over exercises for the individual trainee and relative to trainee’s performance class is displayed. The individual learning curve is plotted over exercises. The administrator has access to all data, including the performance report, a chronologically log file, an assessment sheet registering all important events during the excursive, and a playback feature. Data can be exported.

Most important aspects

The Xitact LS500 is an open platform simulating a clinical procedure including 3D interactivity and Xitact-developed proprietary force feedback. A clinical procedure with its various surgical steps (e.g., the laparoscopic cholecystectomy) is simulated. The scoring system is based on extrapolated clinical patient outcome assessment for the simulation rather than on more indirect performance parameters. Guided and free-format modes exist to complete the procedure. The clip–cut scenery and scoring are validated. Other software modules, for example, the MIST-VR, can run on the Xitact platform.

Shortcomings

Xitact does not incorporate specific software for camera navigation or other “basic skill” tasks for building and evaluation of psychomotor skills. No patient cases are incorporated. The cholecystectomy clip–cut and dissection module are the settings currently available.

Discussion

The term virtual reality refers to a computer-generated representation of an environment allowing sensory interaction, thus giving the impression of true realism [1]. The three ways of "sensing" a virtual world are through sound, sight, and touch. Laparoscopic VR surgical simulators must therefore be able to generate 3D images on a 2D monitor that appear to be "natural" (e.g., moving and behaving in a realistic manner). The simulation must allow a high level of interactivity and be stable and reactive to the surgeon's actions. Haptic feedback is important, preserving the individual an input of tactile sensation. Thus, VR laparoscopic procedural simulators that are valid representations of reality must present organs that are anatomically correct, with natural real-time deformation properties and resistance when manipulated, preserving natural traits such as bleeding or leakage when treated abusively. Furthermore, a good VR surgical simulator must let the surgical resident internalize a surgical procedure without the risk of harming patients. In order to do so, it must provide an environment in which it is possible to learn and perform simultaneously and to have the opportunity to repeatedly practice the same procedure and its possible complications under varying conditions and to get tailored feedback. Ultimately, this process can be translated into an objective examination for certification of that procedure using the same simulator. A prerequisite for a VR simulator that is to be used simultaneously as an assessment tool is a proper validation of the system.

Until recently, most VR training settings focused exclusively on basic surgical psychomotor skills, such as grasping and translocation of virtual objects. Unlike laparoscopic surgery, some of these simulation models did not provide haptic sensations through force feed back. However, force feedback is an indispensable component of a realistic simulation environment. Psychomotor abilities may be trained on the less expensive nonforce feedback type of surgical simulators, which teach more basic laparoscopic skills. The literature suggest that training on these type of simulators will enhance laparoscopic performance. However, it is less likely that training on these types of simulators will lead to true and stable surgical proficiency in a clinical laparoscopic procedure, with all its associated variability. The newer types of simulators do indeed acknowledge and emphasize the importance of force feedback and procedural surgical scenery, and they have force feedback integrated in their systems. Unfortunately, these are still very expensive simulators. The cost: benefit ratio of a simulator is, of course, an important consideration. When the budget permits, since haptics are one of the more costly features embedded in some VR simulators, choosing a simulation platform with force-feedback incorporated is recommended. Although still expensive, these types of simulators will undoubtedly become less expensive as competition increases and technology becomes shared or more widespread. For now, it is recommended that one browse through most recent literature in search for evidence of validation of a system. As can be seen in Table 1, some simulators have cholangiography, whereas others have suturing modules; some can run multiple procedures on the same platform, and others are less expensive.

Finally, it all comes down to the issue of what is most appealing to the public and what has been proven to work as intended. Probably the best way to make a decision is by obtaining hands-on experience with the different types of simulators. Major surgical and MAS conventions, such as those hosted by the American College of Surgeons, the European Association for Endoscopic Surgery, and the Society of American Gastrointestinal Endoscopic Surgeons, offer an excellent opportunity to visit different manufacturers of VR simulators on exhibit. Most manufactures are very willing to provide visitors a hands-on experience on their simulator. For all simulators featured in this review, additional and most-up-to-date information can be obtained from the manufacturers themselves (see Acknowledgments).

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References

1. Coleman J, Duka CCN, Darzi A (1994) Virtual reality and laparoscopic surgery. Br J Surg 81: 1709–1711
2. Gallagher A, Satava M (2002) Virtual reality as a metric for the assessment of laparoscopic psychomotor skills. Surg Endosc 16: 1746–1752

3. Grantcharov TP, et al. (2001) Virtual reality computer simulation: an objective method for the evaluation of laparoscopic surgical skills. Surg Endosc 15: 242–244
4. Grantcharov TP, et al. (2003) Learning curves and impact of previous operative experience on performing on a virtual reality simulator to test laparoscopic surgical skills. Am J Surg 185: 146–149
5. Haluck R, TM (2000) Computers and virtual reality for surgical education in the 21st Century. Arch Surg 135: 786–792
6. Melvin SW, Johnson JA, Ellison CE (1996) Laparoscopic skills enhancement. Am J Surg 172: 377–379
7. Satava RM (1993) Virtual reality surgical simulator: The first steps. Surg Endosc 7: 203–205
8. Schijven M, Jakimowicz J (2002) Face-, expert- and referent validity of the Xitact LS500 laparoscopy simulator. Surg Endosc 16: 1764–1770
9. Schijven M, Jakimowicz J (2003) Construct validity: experts and residents performing on the Xitact LS500 laparoscopy simulator. Surg Endosc 17: 803–810
10. Seymour NE, et al. (1992) Vtrtual reality improves operating room performance: results of a randomized, double-blind study. Ann Surg 236: 458–463
11. Strom P, et al. (2002) Validation and learning in the Procedicus KSA virtual reality surgical simulator. Surg Endosc DOI: 10.1007/s00464-002-9078-1
12. Taffinder N (1988) Validation of virtual reality to teach and assess psychomotor skills in laparoscopic surgery: results from randomized controlled studies using the MIST VR laparoscopic simulator. In: Westword JD (Ed.) Technology and informatics 50: proceedings of medicine meets virtual reality. IOS Press, San Diego, pp 124–130
13. Torkington J, et al. (2001) Skill transfer from virtual reality to a real laparoscopic task. Surg Endosc 15: 1076–1079
14. Versweyveld L (2001) Montefiore surgical residents receive laparoscopic training in freshly opened Virtual Reality and Skills Lab. http://www.hoise.com/vmw/01/articles/vmw/LV-VM-03-01-21.html