Introducing the Xitact® LS500 Laparoscopy Simulator: Toward a Revolution in Surgical Education

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ABSTRACT

Minimal invasive surgery has become the primary technique-of-choice for uncomplicated, symptomatic cholelithiasis. Skills needed for performing laparoscopic cholecystectomy cannot be extrapolated directly from the open surgical technique. An obvious need exists for a valid, objective, and repetitive teaching and training setting for minimally invasive surgery. The surgical skills laboratory may have an important role in acquisition of such skills. New technologies, such as virtual-reality surgical simulation, provide objective, trainee-friendly methods of training. Both surgeons and residents believe it is important to train residents in minimally invasive surgical techniques, using virtual-reality surgical simulation within the context of the surgical skills laboratory. This article highlights the features of one of the most promising technical novelties in the area of surgical virtual-reality simulation, the Xitact® LS500 laparoscopy simulator.

In the past decade, conventional open surgery has been replaced by minimal invasive surgery as the primary technique-of-choice for a number of surgical procedures. The laparoscopic cholecystectomy has largely replaced the open procedure as the standard surgical technique for uncomplicated symptomatic cholelithiasis.[1] Whereas demand for minimally invasive surgical techniques evolve rapidly—driven by such benefits as shorter hospital stay, shorter recovery time, favourable aesthetic results, and reduced consumption of analgetics—surgical training has changed little since. Junior surgeons continue to develop knowledge and skills through studying, observing, and ultimately performing the procedure guided by their surgical instructor. Outcome on the first procedures is likely to be influenced by the

Figure 1. Xitact® hardware.

learning-curve effect, and many complications and variations cannot be taught due to an unacceptable risk to the patient.[2] Surgeons who apply minimal invasive techniques are challenged at an even higher level by a physically demanding operating environment, lacking direct view of organs, reversed kinematics, and restricted haptic feedback.

For cholecystectomy, skills derived from performing the open procedure cannot be extrapolated directly toward the laparoscopic setting, as the laparoscopic technique requires distinct psychomotor abilities and hand-eye coordination. Furthermore, residents no longer perform the open procedure *before* beginning with the laparoscopic cholecystectomy, as the open procedure is no longer the golden-standard procedure for uncomplicated cholelithiasis. Therefore, minimal-invasive techniques pose a pressing need for new training techniques, especially because practice on patients comprises ethical considerations, and animal models are often expensive, not available regularly, and require a highly regulated infrastructure. The surgical skills laboratory may have an important role in acquisition of skills in minimal access surgery.[3-5]

New technologies, such as virtual-reality surgical simulation, provide objective and repetitive methods of training, and a trainee-friendly teaching environment. These technologies, currently under development and soon to be implemented, are promising and likely to have an important role in future surgical education and training.[6] Ideally, such a simulation presents a computer-generated, 'natural' representation of the surgical arena and allows sensory (sight, sound, and touch) interaction. The nature of laparoscopic surgery makes it likely to benefit from training models derived from virtual-reality settings.[7]

Studies have shown potential and interest for virtual-reality trainers in the field of laparoscopic surgery in terms of training and assessing surgical skills and performance.[8-18] Most virtual-reality training settings focus on the basic surgical psychomotor skills such as grasping and translocating of virtual elements. Unlike laparoscopic surgery, many simulation models do not provide haptic or force feedback. Force feedback is, however, an indispensable component of any realistic simulation environment. Until recently, no proper virtual-reality settings that provide haptic sensation and a realistic surgical scene for one of the most commonly featured endoscopic procedures (e.g., the laparoscopic cholecystectomy) were available. Combining force-feedback technology with a realistic interactive surgical simulation environment, the Xitact® LS500, a laparoscopic surgical simulator, is a novelty nearing practical and validated implementation of virtual-reality technology in the standard surgical training curriculum.

THE XITACT® LS500 LAPAROSCOPY SIMULATOR-THE THOUGHT

Xitact® SA, the manufacturer of the Xitact® LS500 laparoscopy simulator, was founded in Morges, Switzerland in April 2000 with the intention of becoming the market leader in the emerging field of medical simulation. A unique project was developed that involves expert surgeons in the field of laparoscopic surgery working alongside technical hardware and software engineers. For the first time in surgical history, experts from the medical as well as technical communities are pioneering together from the beginning to build a valid and truly realistic virtual-reality laparoscopy simulator. Continuous feedback from this Scientific Advisory Board* is provided through frequent interactive meetings. Development of the simulator is, thus, monitored regularly and adjusted accordingly.

Another important aspect in development of the simulator are validation studies, which provide highly valuable data on acceptance of the simulator in the surgical community as well as comments for further improvement.[19]

* *Members of the Scientific Advisory Board: Prof. Sir Alfred Cushieri, University of Dundee, Scotland; Prof. Richard Satava, University of Yale, United States of America; Dr. Jack Jakimowicz, Catharina Hospital Eindhoven, The Netherlands.*

THE XITACT® LS500 LAPAROSCOPY SIMULATOR-THE SYSTEM

The Xitact® LS500 Laparoscopy Simulator is a virtual-reality training setting developed for training and education of a variety of laparoscopic skills. It is a hybrid simulator, which combines a physical object (the OpTable, or 'virtual abdomen') with a built-in computer that provides visual images, haptic feedback, and data recording (Fig. 1).

HARDWARE

The hardware of the Xitact® LS500 is a modular system containing an:

- OpTable Operation Table. The OpTable-console (0.6 m×0.7 m×0.7 m, 50 Kg) houses the 'abdomen' of the virtual patient, endoscopic instruments, and endoscopic camera. Two instruments are mounted in the OpTable, with the possibility of using a virtual third instrument by use of a 'freeze' software-generated option. The instruments have high-

Figure 2a. Xitact® virtual-reality scenery: voiced-over instructional videoclips.

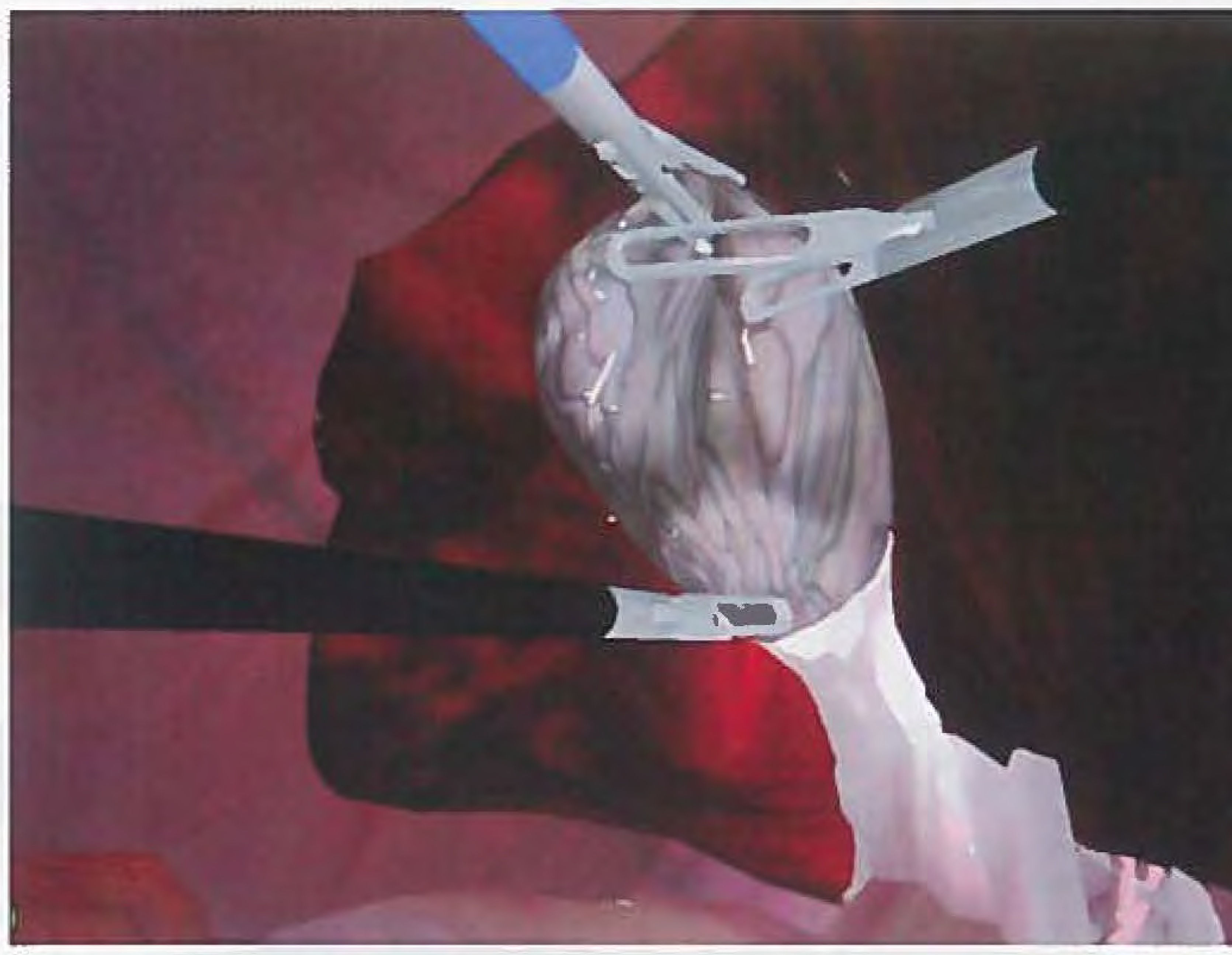

Figure 2b. Virtual-reality setting: exposure of gallbladder.

Figure 2c. Virtual-reality setting: clipping of cystic duct.

Figure 2d. Virtual-reality setting: cutting of cystic duct.

performance Force Feedback with five degrees of freedom, which feature performance, precision, and force feedback on original endoscopic instruments. One endoscope is mounted, with four degrees of freedom, which offers several optical axis angles that feature a freeze-picture switch combined with adjustable positioning possibilities. The console is topped by an exchangeable port-positioning matrix, which enables various trocar-placement possibilities for different procedures. The OpTable's height is adjustable according to the operator's height with a Trendelenburg capacity, and the OpTable has a connected 2-pedal foot switch for simulation of electrosurgical coagulation.

- Ebox Electronic Box. The Ebox (0.6 m × 0.7 m × 0.6 m, 25 Kg) houses the electronics of the system and is connected to the OpTable. The box includes: a swivel with a independent and freely movable, flat panel 18'TFT monitor with a resolution of 1280*1024 pixels, an Industrial Personal Computer, system memory 512 MB Ram, disk space 20GB hard disk. The operating system is Microsoft Windows 2000 Profesional, CPU Intel™ Pentium III 1 GHz, Video: GeForce II GTS.

The electric characteristics of the system include a Mains voltage of 100-249 V, 50-60 Hz, and a maximum power consumption of 750 W for the entire system.

SOFTWARE

The simulator features the laparoscopic cholecystectomy exposure module, the laparoscopic clip-and-cut curriculum and the laparoscopic peritoneal cholecystectomy dissection curriculum. The curricula include step-by-step tutored task modes and free-format modes. The tutored task mode guides the trainee through the procedures of retraction, clip applying and cutting, sharp dissection by scissors, and the use of diathermia with the electrocautery hook while performing the 'tenting technique' for the peritoneal dissection of Calot's triangle. It provides clues for correct postioning of clips and cutting location and the ideal dissection area. Both the tutored-task mode and the free-format mode include performance recoding and scoring. Currently under construction are the laparoscopic sterilization and ovariëctomy. The systems' software incorporates a combination of multimedia elements including text, surgical video clips with voice-over,

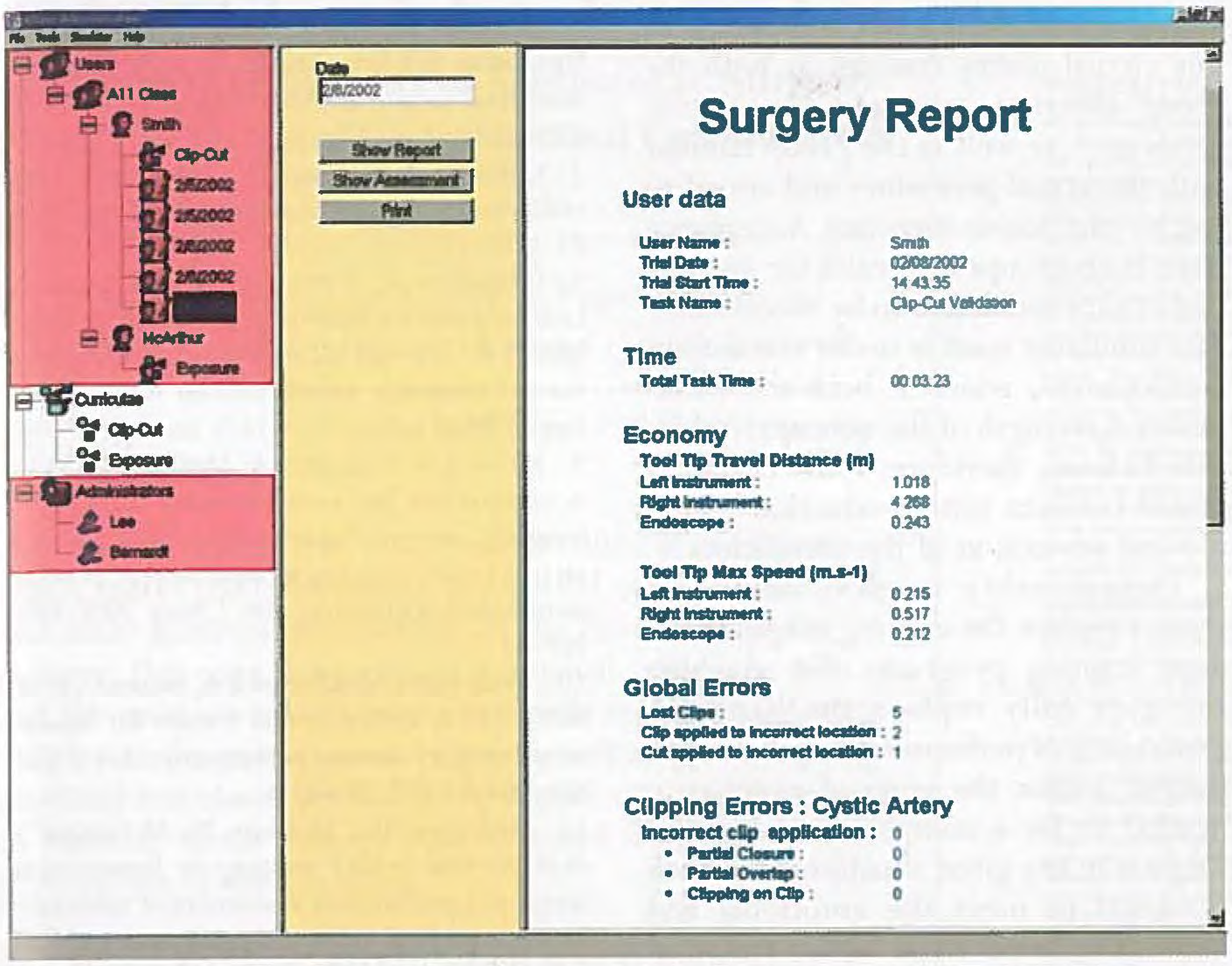

Figure 3a. Surgical report administrator mode.

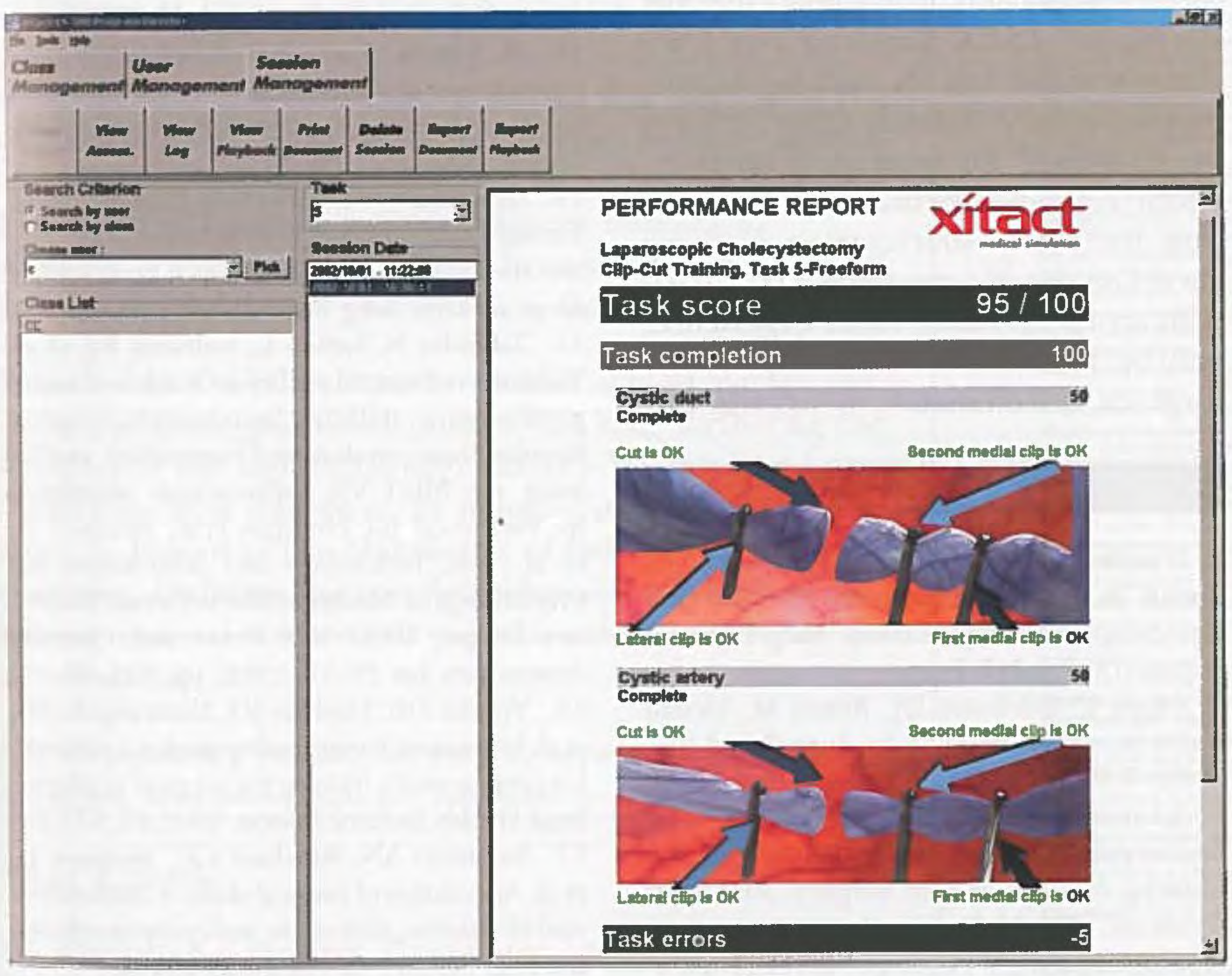

Figure 3b. Performance Evaluation.

simulation recordings, and example patient cases. Tasks of the laparoscopic cholecystectomy procedure (insufflation, trocar placement, exploration, clipping, cutting, separation, extraction, and closure) are demonstrated. The various aspects of the procedure can be assigned and repeated in any desired combination. Different anatomical varieties of Calot's triangle are currently under construction (Figs. 2a-2d).

COMPUTER

Data recorded by the computer include time per task and error rates (loss and incorrect placement of clips). Real-time analysis of hand motions to provide continuous assessment of skill performance is possible, as tool trajectories are recorded.

SURGICAL EDUCATION USING THE XITACT® LS500 LAPAROSCOPY SIMULATOR

A definite need exists for a comparable, objective means of assessment regarding residents' surgical skills and competence. In the surgical curriculum, few formal and validated tests are being posed upon residents, and most of them do not measure residents' actual level of skill. The classic surgical apprenticeship model, with all its built-in subjectivity of assessment, permits residents to proceed with their training program. A more objective method of validation of residents' skills would be welcomed as an adjective to this classical model.

The Xitact® LS500 laparoscopy simulator, in addition to simulation, generates data on efficiency, motion-track analysis, and error rate upon interaction. The system provides a unique tool for objective assessment of the surgeon's performance. This property appears to be a major feature for many surgeons involved in teaching laparoscopic surgery.[5] Another major advantage of the system is that it provides a tension-free environment to train and (self) assess the residents' progress. Recent studies have shown that 91.9% of residents and 88.2% of senior surgeons, who have trained with the Xitact® LS500 simulator, believe it provides a user-friendly environment for training laparoscopic skills. Also, both residents and senior surgeons believe it is important to monitor residents in their progress on laparoscopic skills throughout their residency by using a laparoscopic virtual-reality setting (74.7% of residents, 84.6% of surgeons).[19]

Training sessions on the Xitact® LS500 simulator can be built according to the level of the trainee, and feature different tasks as would be performed normally in laparoscopic cholecystectomy.

A typical training session comprises different elements. Didactical information, such as a voiced-over video of the task under study, is combined with a representation of the most-commonly featured errors accentuated. Next, the virtual-reality abstraction of the task under study is shown in a demonstration video.

The actual simulation task (e.g., clipping and cutting of the cystic artery and duct) can be provided by logging the trainees' data simultaneously.

After completion of the tasks, trainees can assess their performance through the automatically generated surgical report, which features aspect as time, motion analysis, and error rates. Also, a replay of the virtual-reality procedure is available. All performances of the trainee are logged into the system, so improvement in time (learning curve) can be monitored (Figs. 3a, 3b).

The system also incorporates a program-director module for the surgical expert to guide the trainees. Curriculum construction, performance reporting, and possibilities for data analysis are included under this module. User accounts and user groups, with specific and individualized training curricula, also can be set up (see Figs. 3a, 3b).

FUTURE OF THE XITACT® LS500 LAPAROSCOPY SIMULATOR

A proper virtual-reality surgical simulator must offer the possibility for the surgical resident to internalise a procedure without the risk of harming patients, learn and perform simultaneously, and have the opportunity of repeatedly practising varying scenarios of the same procedure under varying conditions. Ultimately, this process can be translated into an objective examination for certification of that procedure using the exact same machine.[2] The modular, user-friendly, and self-assessment system of the Xitact® LS500 laparoscopy simulator is appealing, and has the adaptability of apparatus to new surgical software modules for different surgical procedures. The system can be used as a training platform itself, but also to validate laparoscopic training courses or improvement of residents' skills in the surgical curriculum.

Both residents and surgeons who have become acquainted with the system are enthusiastic. They validate global realism of the virtual-reality environment highly (overall mean 3.42 on a 5-point scale), as well as haptic sensation of the simulation (overall mean of 3.66).[19] Residents and surgeons do not differ significantly in their opinions, which indicates enthusiasm and acceptance of this virtual-reality concept in both the group aimed to train and use it—the residents—as well as the group familiar with the actual procedure and aimed to teach—the senior surgeons. Acceptance from both groups is needed for any virtual-reality simulation to be successful.[19] The simulator itself is under continuous development, which is both the weakness and strength of the concept. A delicate balance, therefore, must be maintained between time-production schedule and perfection of the simulation.

Virtual-reality surgical simulation cannot replace the existing surgical resident training programs. No machine can ever fully replace the hands-on experience of performing surgery on the patient, mimic the years of experience needed to be a competent and skilful surgeon in any given situation, and teach residents to meet the emotional and demanding needs to be both a technical skilled surgeon and an empathic counsellor to the patient. However, both surgeons and residents believe uniformly that the Xitact® LS500 simulator could become a useful tool in teaching laparoscopic cholecystectomy (resp., 90.9% vs. 97.9%).[19] An integrated scenario, which combines virtual-reality simulation for safely shortcutting learning curves on specific procedures combined with actual operating room experience, will be beneficial to residents, senior surgeons, and ultimately, to patients. STI

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