S.P.I.C. Pedagogical Simulator for Gynecologic Laparoscopy.

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Summary

Laparoscopic surgery has numerous advantages, but this technique is difficult and requires specific training. This paper presents a simulator for gynecologic laparoscopic surgery called S.P.I.C. (Pedagogical Simulator for Gynecologic Laparoscopic Surgery), specifically designed for teaching. It includes a rail with 3 trocars already in place, and a computer monitor. Training using the simulator is divided into tasks and steps in order of increasing difficulty. Each step consists of training exercises and evaluations. Learning with the simulator is guided by software that allows instructors to personalize their lessons. This prototype has allowed us to put into place training for spatial localization and manipulation of surgical instruments in the abdominal cavity. An evaluation at a clinical site has allowed us to determine the improvements to be made on this prototype. Training with a simulator is part of a resident's regular curriculum and is not meant to replace on site hospital experience. Some imperfections in imaging still exist, due to inevitable technical limitations. Our initial choice was to emphasize realism and "real time", rather than the "aesthetic quality" of the images. Furthermore, by limiting our graphic expectations, we have been able to create a simulator at a reasonable overall price. The S.P.I.C. training tool remains experimental and is still in the process of being developed.

Introduction

This paper presents a simulator for gynecologic laparoscopic surgery called S.P.I.C. (Pedagogical Simulator for Gynecologic Laparoscopic Surgery). It was created to respond to the training needs in gynecology associated with the need to modernize the methods used to evaluate surgeons [1]. A study done between January 1992 and March 1993 surveyed 602 surgeons and laparoscopists throughout Europe about their training needs: More than 96% of the respondents think that surgeons would benefit from training with a model before starting to operate on actual patients, even with a mentor present [2]. The creation of S.P.I.C. was the result of collaboration between complementary teams of computer scientists, electronics engineers, micro-mechanical engineers and gynecologists from Lille

(France) who specialize in laparoscopy. Unlike several other projects that are currently being developed throughout the world, the originality of this simulator is that it is strictly a pedagogical tool [3].

Gynecologic Laparoscopic Surgery and current training methods for this technique

The peritoneal cavity is inflated with the help of an insufflator. A camera is introduced near the umbilicus by way of a 10 mm trocar. The camera projects onto a video monitor the image with which the surgeon will work. For completing the surgery itself, one or more instruments are introduced through the trocars near the fossa iliaca. There are numerous advantages to laparoscopy: A decrease in hospitalization time and postoperative pain, a lower rate of morbidity and finally, a decrease in aesthetic damage. It is possible to perform many gynecologic operations using laparoscopy and in certain cases, it is actually the preferred method. However, this surgical procedure has specific limitations: The surgeon has only an indirect view of the site of operation. He (or she) must mentally reconstruct reality based on the video projection. The instruments are mounted onto the end of a handle about 20 cm long, which makes manipulating them a subtle, precise and delicate task. The abdominal cavity is small and accessing certain structures is very difficult [4]. All of the current publications dealing with gynecologic laparoscopy show that the number of complications during an operation is related to the experience of the surgeon, and that mastery of these techniques is necessary for all operations, even the simplest ones [5, 6].

Because of the previously mentioned factors, rigorous training for this technique is a necessity. Today, residents who specialize in gynecologic surgery are trained by apprenticeship with professional surgeons on actual patients. This system have well known limits : risks to the patient, availability of the surgical mentor and of operating rooms. The training is also done on animal models such as pigs. This training technique is limited by the cost of the animals and their preparation and care, as well as by the availability of surgical mentors and the ethical problems associated with the sacrificing of animals for surgical purposes. The residents have a Pelvitrainer™ at their disposal. The Pelvitrainer™ is an inert box made of plastic with an opaque lid, which has holes in it to allow for insertion of instruments. Actual instruments must be used. Experience has shown that the Pelvitrainer™ was seldom used in practice. Training is occasionally done with fresh cadavers, which have the advantage of being anatomically identical to actual patients. However, the cadavers' tissues present macroscopic aspects and reactions that are very different from those encountered during an actual operation (absence of bleeding…). Furthermore, the preparation and care of cadavers remain expensive tasks [7, 8, 9]

Other Laparoscopic Simulators

Other researchers throughout the world are working on training simulators, such as flight simulators for civil or military purposes, etc. Until now, prohibitive cost has kept simulation tools from being used in the medical field. Recent advances in computer technology and imaging have now made it possible to envision developing such tools at a reasonable price, therefore making them accessible to most universities and hospitals in the developed countries. A French team builds, with the Thomson enterprise, a laparoscopic simulator to repeat some surgical procedure before to perform them on a true patient [10]. Their way of learning is very closed from the military one. They don't have any force feedback either any training program. A German team makes the SUSILAP G - Simulation System [SUrgical SImulator for LAParoscopy in Gynecology) [11]. It contains two Laparoscopic Impulse Engines from Immersion Corp™. and a computer monitor. The graphical interface is based on Open Inventor. They are currently using a Silicon Graphics Onyx2 Infinite Reality™ who is very performed but very expensive. With this system a virtual sterilization can be performed by coagulating a fallopian tube. They just simulate the Fallopian tube with an elastic mesh, because it is the only manipulated organ. The resulting deformation causes a force feedback, which can be felt through the Impulse Engines using haptic rendering. MIST VR (Minimally Invasive Surgical Trainer Virtual Reality) is an English surgical simulator who comprises a frame holding two standard laparoscopic instruments (Virtual Laparoscopic Interface from Immersion Corps™) linked to a computer [12]. The training program is based on keys surgical technique employed in laparoscopic cholecystectomy, using simple geometrical shapes rather than tissues. The performance is measured by time, number of errors and the efficiency with which the exercise is performed.

Our pedagogical gynecologic laparoscopic simulator and its objectives

The pedagogical laparoscopic simulator consists of a rail with 3 located trocars, a PC and software for managing the graphical part of the training protocol. For each trocar, the instruments are already in place. There is also a computer monitor similar to the video monitor used during actual operations. This tool is used with software that runs a program for training the students and accessing the data. In our simulator, the extra-abdominal parts of the instruments are there, but their functions are simulated. The modeling of the pelvic cavity is based on intra-abdominal measurements of the patients after pneumoperitonium has been achieved [14]. The pelvic organs have been modeled according to information in anatomical reference books [15, 16]. Organs located using the simulator can thus be easily located in an actual patient, without adaptation.

This prototype has allowed us to put into place a training tool for spatial localization and for manipulation of the instruments in the abdominal cavity [3, 17]. It is autonomous, i.e.; the students may use it without an instructor present, which allows for a more objective evaluation of the students' level. The prototype trains students to:

1. Locate points of reference in the abdominal cavity.
2. Frame the structures to be worked on: Framing should be accomplished equally well with the left or right hand.
3. Locate the position of the instrument in relation to anatomical structures. They must locate the placement of sub-peritoneal structures.
4. Move the instruments without taking their eyes off the screen
5. Evaluate distances in the abdominal cavity.
6. Coordinate movements with the left and right hand.
7. Place the camera at the appropriate distance from the instrument: In order to zoom in on a structure, the student needs to perfectly frame the work zone into the center of the screen and also enlarge the image "in doses" to avoid being blinded.

Limitations of the simulator for gynecologic laparoscopy

Training with a simulator is part of a resident's regular curriculum and does not claim to replace traditional training by apprenticeship. Thus, the laparoscopic simulator is not intended to teach surgical techniques, which are quite adequately described in numerous books. Rather, this training tool allows for the acquisition of dexterity in manipulating the surgical instruments. This technical competence, once acquired, makes it possible for the students to spend the most time possible on other aspects of their training as future laparoscopists. There are still some imperfections in the visualization of the computer images because of inevitable technical limitations. As the contours of an organ represented on the screen are "smoothed out", the number of facets increases, and therefore the speed of display is slowed down. The speed of display cannot be slowed down to below 10 Hz without compromising the real time interactivity of the simulator. Our initial choice was, and still is, to emphasize realism and "real time", rather than the "aesthetic quality" of the images.

Results

The training is divided into four tasks, which are themselves divided into steps of increasing difficulty [3, 17]. The tasks are:

1. Working with just the camera.
2. Working with one instrument and a still camera.
3. Working simultaneously with the camera and an instrument
4. Working with two instruments, the camera is still, or held by an aid.

Each step consists of a group of exercises divided into two sections: The training section is made up of various exercises of increasing difficulty that the students choose from a list corresponding to their level. They may also review the work they have just completed and consult a detailed evaluation sheet, which consists of a graded evaluation of their performance, the type of error most often made and an overall evaluation of the results obtained. The evaluation section is made up of an exercise to be completed, an evaluation sheet with graded evaluation of the results, overall comments, and permission to go on to the next step if the results are satisfactory. The students may choose to train or to be evaluated. The evaluation exercises for each task and step, and at the end of training with the simulator, are different every time to prevent students from learning the exercises instead of learning the technique.

Teaching with a simulator is guided by a software program that allows instructors to individualize the training they wish to give their students. They may or may not choose to be present during the evaluation sessions. The instructors only need to be present for the final evaluation since they are in charge of approving the overall training with the simulator. Each instructor can modify the parameters (the conditions for completing the exercises) and the criteria for successfully mastering the exercises. They may also create or remove exercises. The students are monitored with this same software, which allows the instructors to authorize access to the training tool and to follow their students throughout their training.

The post-training evaluation is the only way to guarantee that the simulator does not have adverse effects, such as creating the feeling that the user is trained and competent after just a few hours of work on it. Another possible adverse effect is that the students learn to complete the exercises as quickly as possible, compromising the most basic safety regulations. We have always opted to create time guidelines for the exercises that allow us to respect the security of the patients. The evaluation is based on the hypothesis that a student using S.P.I.C. acquires dexterity in manipulating the laparoscopic tools more quickly and efficiently. The hypothesis is supported by a randomized comparative study: The first group (10 cases) has access to the S.P.I.C. as well as traditional training whereas the second group (9 cases) of residents follows the traditional training by apprenticeship. A panel of 5 experts evaluated all of the residents during a training session using pigs, at the beginning of the study (To) and at the end of the training period (T1), two months later. The purpose of analyzing these two evaluations was to study the effects of learning with a simulator on the grades obtained ("S.P.I.C. effect"). We used the Analysis of Principal Components (APC), the Wilcoxon test, the Spearman coefficient and the Fleiss method. The Fleiss method gave the experts' grading system a good reliability coefficient. However, our study did not demonstrate, in a statistically significant way, the overall efficiency of the S.P.I.C. in teaching basic laparoscopic surgical procedures (Wilcoxon test $p>0.05$) [18].

Conclusion

The technical imperfections of the graphic imaging are not bothersome since the simulator offers a degree of realism that is not perfect, but quite sufficient for the students to feel as though they are “performing an operation”. Moreover, by limiting our expectations for the quality of the virtual reality, we were able to create a low cost simulator. This limits the overall cost and allows more hospitals to have access to it. Access to the pedagogical protocol is limited to the instructors and guarantees that they will maintain control of the training content given to their students. This allows the instructors to adapt the new pedagogical tool to their specific needs.

The objectives of teaching laparoscopic techniques with a pedagogical simulator are twofold: 1) that the students attain a certain amount of dexterity allowing them to more quickly begin working in the operating room, 2) to become more reliable and thus begin their practice with actual patients in the best conditions.

The pedagogical simulator for laparoscopy needs further development. We have already begun work on improving it by including programs for force feedback and organ deformation, which would occur while manipulating or cutting the pelvic organs. We intend to model gynecologic pathologies. We envision modeling structures that are not visible during an actual laparoscopic surgery, such as the ureter and so. These images, which are more augmented reality than virtual reality, could show students the location of these structures and make them aware of the risks that they must take in completing certain surgical procedures, which force them to come very close to these important, yet fragile and invisible structures.

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