2007

Medicine Meets Virtual Reality 15

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Virtual Reality for Robotic Laparoscopic Surgical Training

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Abstract: Virtual reality (VR) simulation has been used to improve training for manual laparoscopy and to give surgeons superior performance in the operating room. However, VR has not been used to train surgeons in robotic laparoscopy. *Subjects:* Five students of the University of Nebraska Medical Center (UNMC) and the University of Nebraska at Omaha gave consent according to UNMC ethical guidelines. *Experimental protocol:* Subjects performed with the Da Vinci robotic surgical system 5 trials for each of two tasks (Bimanual Carrying, BC; Needle Passing, NP). Each task was performed first in the actual robotic operating environment and then in VR. The data analysis included time to task completion, instrument tips distance traveled and the corresponding speed, and range of motion of the elbow flexion and extension of each subject. *Results:* The BC and NP tasks were not significantly different between the two environments with respect to robot tip speed and the elbow range of motion for both arms. Time to task completion and distance traveled were significantly different between the two environments for both tasks. Survey results showed that subjects partially agreed that it was easy to adapt to VR and felt comfortable manipulating the robot controls in VR. They also suggested that they would like to have VR as part of their regular training. Our preliminary efforts showed promise that our VR environment is valid and it can be used for training of robotic laparoscopy. However, the differences identified need to be further explored and point to the need to further improve our VR simulation.

Keywords. Virtual reality, laparoscopy, surgical robot, daVinci, surgical training

Background

Virtual reality (VR) simulation has been used to improve training for manual laparoscopy and to give surgeons superior performance in the operating room [1, 2]. However, to date there has never been a VR developed to train surgeons involving robotic laparoscopic surgery (Robotic daVinci Surgical System; dVSS; Intuitive Surgical Inc.). Our study presents preliminary efforts to develop a VR training environment for robotic laparoscopy. In addition, we compared our prototype VR environment to the actual environment, the dVSS, using simple tasks (needle passing and bimanual carrying) to determine the validity of the simulation.

Tools and Methods

Subjects: Five right hand dominant experienced daVinci users were recruited from the University of Nebraska Medical Center (UNMC) and the University of Nebraska at Omaha. Each subject signed a consent form according to UNMC ethical guidelines.

Tasks/Experimental protocol: Subjects performed two tasks: bimanual carrying (BC), and needle passing (NP). The tasks were performed in both the actual and the VR environments. The tasks were cyclical in nature and were designed to mimic actual laparoscopic tasks that require significant bimanual coordination. In the real environment BC task as in Figure 1a, the subject was first instructed to simultaneously pick up a 15 x 2 mm plastic piece (one each with left and right robotic graspers) from metal caps (30 mm in diameter) and then to place them in two other metal caps 60 mm away. The subjects reciprocated bimanual carrying movement five times in succession in one trial. A total of five trials were collected. After the real environment task was completed, a VR simulated BC task was performed as in Figure 1b. In the VR environment, the subject also performed five trials.

For the real environment NP task, the subjects were first instructed to use the right dominant arm to pick up a 26 mm surgical needle from a fixed location and then pass it through 6 consecutive 8mm in diameter holes of a latex tube for one trial. The tube was 14 cm in length. When passing through each hole, the left grasper picked up the passing needle. After the completion of five trials in the real environment, the VR simulated NP task was performed. In the VR environment, the subject also performed the same reciprocal passing movements between the two graspers.

Virtual Reality Construction: The VR environment for each task was developed using Webots 5.1.8 software (Cybertronics, Ltd, Switzerland). Each VR task was driven with kinematic data streamed in real-time from the daVinci robot's operating console through data acquisition software (LabVIEW 8.1, USA). The daVinci's instruments and each task's environment were modeled as 3D objects using SolidWorks (USA). In the BC VR simulation (see Figure 1b), virtual grasping and release of the target plastic pieces were based upon touch sensor information built-in between the instrument tip and the plastic target pieces. When both virtual instrument tips simultaneously touched the targets in each cup, the VR environment signified discrete events to relocate the targets to other cups. Reciprocal touching the target in the cups simulated the bimanual carrying movement in the actual robotic operation environment. In the NP VR simulation, a design of the built-in sensor touch between the instrument tip and virtual targeting hole on tube simulated the needle passing and retrieval. To view each VR task in the daVinci surgeon console, a virtual laparoscopic camera was built to project the virtual task to the viewing area of the console as a 3D stereoscopic image.

Figure 1. Robotic laparoscopic bimanual carrying task in a). Actual, b) VR environment

Data Collection and Analysis: Kinematics of the dVSS was collected at 100 Hz using the Application Programmer's Interface provided by the manufacturer. Elbow flexion and extension angles of each subject were also collected at 1000Hz using electrogoniometers (Biometrics, Ltd. USA). Analysis included time to task completion, instrument tip distance traveled and the corresponding speed, and range of motion of the elbow. Paired *t*-tests were used to compare the VR and the actual environment. Each subject was also asked to complete a written survey.

Results

The BC and NP tasks were not significantly different between the VR and actual environments with respect to the robot tip speed and the elbow range of motion for both arms (see Figure 2). However, time to task completion and distance traveled were significantly different between the VR and the actual environments for both tasks. Results of the written survey showed that subjects partially agreed that it was easy to adapt to VR and felt comfortable manipulating the robot controls in VR. They also suggested that they would like to have VR as part of their regular training.

Conclusion

Our preliminary findings showed that a promise of the developed VR environment can be potentially implemented for training of robotic laparoscopy. However, the differences in the time to task completion and the distance travel of the instrument tips suggest a need of improving the current VR environment. In future study, studies will be conducted to examine the effects of training between VR and actual environments in robotic laparoscopy[1].

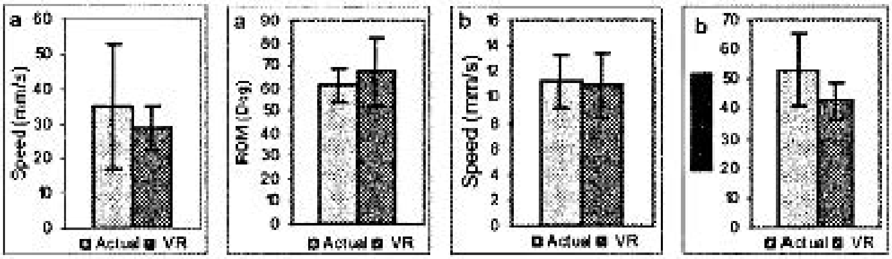

Figure 2. Tip speed and Range of Motion for a) BC and b) NP tasks, $p > .05$

REFERENCES

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