Desktop-Based Computer-Assisted Orthopedic Training System for Spinal Surgery

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BACKGROUND: Simulation and surgical training has moved on since its inception during the end of the last century. The trainees are getting more exposed to computers and laboratory training in different subspecialties. More needs to be done in orthopedic simulation in spinal surgery.

AIMS: To develop a training system for pedicle screw fixation and validate its effectiveness in a cohort of junior orthopedic trainees.

TRAINING SYSTEM: Fully simulated computer-navigated training system is used to train junior orthopedic trainees perform pedicle screw insertion in the lumbar spine. Real patient computed tomography scans are used to produce the real-time fluoroscopic images of the lumbar spine.

MATERIAL AND METHODS: The training system was developed to simulate pedicle screw insertion in the lumbar spine. A total of 12 orthopedic senior house officers performed pedicle screw insertion in the lumbar spine before and after the training on training system. The results were assessed based on the scoring system, which included the amount of time taken, accuracy of pedicle screw insertion, and the number of exposures requested to complete the procedure.

RESULTS: The result shows a significant improvement in amount of time taken, accuracy of fixation, and the number of exposures after the training on simulator system. This was statistically significant using paired Student t test ($p < 0.05$).

CONCLUSION: Fully simulated computer-navigated training system is an efficient training tool for young orthopedic trainees. This system can be used to augment training in the operating room, and trainees acquire their skills in the comfort of their study room or in the training room in the hospital. The system has the potential to be used in various other orthopedic procedures for learning of technical skills in a manner aimed at ensuring a smooth escalation in task complexity leading to the better performance of procedures in the operating theater. (J Surg 71:805-809. © 2014 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: training system, spinal fractures, computer navigation, simulation

COMPETENCIES: Practice-Based Learning and Improvement, Systems-Based Practice, Medical Knowledge

INTRODUCTION

Surgical training has progressed from the era of doing the training on the plastic bone simulator to 3-dimensional (3-D) simulation using special monitors and cameras.[1] As surgeons, the primary goal of our training is to provide the best care to our patients. However, there is always a scope for improvement in surgeon education and training, and simulation can provide a platform for solving these training riddles.[2] More and more orthopedic training programs are making the simulation training a mandatory part of the training. The challenges of reduced training opportunities, shortened working hours, and financial pressures[3] have been exemplified by the increased pressures on the hospitals to achieve targets and focus on service provision. Trainees are developing their psychomotor skills in their later years of training, and highly specialized surgeries like spinal surgery are mainly done by the consultants or the fellows who have decided on their subspecialty.[4] Training simulators are available to the selected few, and most trainees have to register to courses and workshops to do simulation for the specific procedures. Simulation systems provides stress-free

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environment for junior trainees to learn surgical skills.[5] Simulations are used to augment training in the operating room, and trainees acquire their skills in structured manner aimed at ensuring a smooth escalation in task complexity to improve performance in the theater.[6] It also gives an opportunity for the trainers to assess the trainees on simulator before they can perform the surgery on the actual patients.

Intraoperative fluoroscopy is the tool for navigating the surgeon in the 3-D space using 2-D images. Orthopedic surgeons are accustomed to using this 2-D image data to navigate the surgical instruments in a 3-D space. This is commonly called as the mental navigation, similar to aeronautical navigation. The use of fluoroscopy is of paramount importance in the spinal surgery where the surgeon is working close to the spinal cord and a single mistake can lead to catastrophic complications. Though senior surgeons are used to doing complex procedures without much difficulty, it becomes a daunting task for the junior trainees to learn this skill in the operating theater.

Computer-aided surgery has been used extensively in recent years in various surgical disciplines including the spinal surgery.[7-9] Most of the research has been done in the past on the use of computer navigation in performing surgery.[1,6,9] The use of simulation training is still in its infancy when it comes to training in spinal surgery. The procedure for pedicle screw placement is complex and technically demanding with a steep learning curve.[10,11] The present study tries to test the usefulness of computer-assisted orthopedic training system in the development of mental navigation of the surgical trainee in 3-D space for the common spinal procedure like pedicle screw fixation. The study is initially used to train orthopedic trainees in placement of pedicle screw fixation and see the improvement in their performance after training on computer-assisted orthopedic training system.

Computer-Assisted Orthopedic Training System

We use the computer-assisted orthopedic system developed by the Simulation and Visualization Research Group, of which earlier versions have been in use since 1992.[1,12,13] The system has been modified since its initial development to be the desktop system with no use of the fluoroscope and the saw bones. The computed tomography (CT) scan image is loaded into the system, and it produces real-time fluoroscopic images. Using polaris tracking system, computer-assisted orthopedic system allows real-time image-interactive navigation of the surgical tools with respect to the 2 preacquired radiographic images processed from the CT scan. The system does not need to acquire any radiographic images during the surgery, and the images are generated by the computer-assisted orthopedic training system from the CT scan. The computer also allows noncontact measurement of precise angles and depth of surgical tool penetration of bone.

Use of Computer-Assisted Orthopedic Training System in the Training of Pedicle Screw Insertion in the Lumbar Spine

Pedicle screw insertion is one of the most commonly performed steps in the spinal surgery and spinal fracture fixation. Orthopedic trainees learn to do this procedure much later in their training career, and simulation with feedback for this procedure is hardly available.

Computer-assisted orthopedic training system uses CT scan–generated images to register the bone and landmarks. The system has an admin mode where the trainer can put the desired CT scans onto the system. The system identifies the bony cortices and generates 2 image (anteroposterior and lateral) views for the trainer to confirm the landmarks on the bone. The trainer in the admin mode of the system analyzes these images and decides the desired trajectory of the screw. The computer-assisted orthopedic training system guides the trainee to correct orientation and position in the training mode. The assessment mode assesses the performance of the trainee and gives the scores based on the scoring system.

MATERIAL AND METHODS

The study was designed to include junior orthopedic trainees from the local hospital. All the junior surgical trainees who had not done any spinal surgery and had no previous exposure to computer-assisted orthopedic training system were included in the study. Our hypothesis is that the group that was exposed to computer-assisted orthopedic training would have the same performance as the group that was not exposed to computer-assisted orthopedic training.

The trainees were randomly divided into 2 groups.

Group 1 (Who Had Navigation Training)

Initial part of the study involved the use of conventional computer-assisted orthopedic surgery system to train this group of orthopedic trainees. This group was trained using the computer-assisted orthopedic surgeries system for pedicle screw insertion in the lumbar spine (6 Trainees).

Group 2 (With No Navigation Training)

This group would have no exposure to such training (6 Trainees).

The control group was made of equal number of trained orthopedic surgeons who routinely do spinal surgery so that the scoring system can be validated and the 2 groups can be compared with the control group.

The 2 groups are also compared for the difference of exposures required to perform the task and amount of time required to finish the task.