Computer-Assisted Orthopedic Training System for Fracture Fixation

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Background

Surgical training has been greatly affected by the challenges of reduced training opportunities, shortened working hours, and financial pressures. There is an increased need for the use of training system in developing psychomotor skills of the surgical trainee.

Aims

To develop the training system for fracture fixation and validate its effectiveness in a cohort of junior orthopedic trainees.

Training System

Computer-navigated training system uses the 2 sets of images from the c-arm while the registration phantom is placed in the fluoroscopic imaging space which permits determination of the position of the x-ray source and the image plane that then guides the trainee to navigate the surgical instruments into the three-dimensional space. No further c-arm exposures are taken during the entire procedure.

Material and Methods

The training system was developed to simulate dynamic hip screw fixation. Twelve orthopedic senior house officers performed dynamic hip screw fixation before and after the training on the training system. The results were assessed based on the scoring system that included the amount of time taken, accuracy of guidewire placement, and the number of exposures requested to complete the procedure.

Results

The result shows a significant improvement in the amount of time taken, accuracy of fixation, and the number of exposures after the training on the simulator system. The paired student t-test was used and statistically significant results were obtained (p-value < 0.05).

Conclusion

Computer-navigated training system appears to be a good training tool for young orthopedic trainees. This system can be used to augment training in the operating room and trainees acquire their skills in a “nonthreatening and unhurried environment.” 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.

Key words

- training system;
- fracture fixation;
- computer navigation;
- simulation

Competencies

- Medical Knowledge;
- Practice-Based Learning and Improvement;
- Systems-Based Practice

Introduction

Surgical training has been greatly affected by the challenges of reduced training opportunities, shortened working hours, and financial pressures.[1] There is an increased need for the use of training system in developing psychomotor skills of the surgical trainee.[2] Simulation environment can provide a friendlier and less hazardous environment for learning surgical skills. Simulations are used to augment training in the operating room (OR) and trainees acquire their skills in a "nonthreatening and unhurried environment."[2 and 3] Learning in the operating theater provides little opportunity for practice and reflection, and this is one of the strongest stimuli for taking training in surgical skills into non-OR environments. Task simulations possess the potential to structure the learning of technical skills in a manner aimed at ensuring a smooth escalation in task complexity leading to the performance of procedures in the operating theater.[4]

Intraoperative fluoroscopy is the tool for intraoperative control of long bone fracture reduction and osteosynthesis. It provides a 2-dimensional (2-D) data to the orthopedic surgeon. Orthopedic surgeons are experienced in using this 2-D image data to mentally navigate the surgical instruments into the 3-D space. Mental navigation of the 2-D image into 3-D space requires a lot of practice and training. With the decrease in the training opportunities in theater for the surgical trainee, these skills develop at a much later stage in the training.[5] Several studies have shown a reduction in the number of operations undertaken and the level of competence achieved by surgical trainees.[1] Much of the earlier training years are spent on hit and miss which results in lot of image intensifier exposure as well as the theater time. The use of computer-assisted orthopedic surgery system for the development of these skills in a non-OR environment can help the surgical trainee develop these skills without x-ray exposures.

Computer-aided surgery has been used extensively in recent years in various surgical disciplines beginning with neurosurgery and then expanding to the fields of craniofacial surgery, general surgery, and eventually orthopedic surgery.[6 and 7] In orthopedics, its use has been well accepted in spinal surgery.[8] It has also started to make inroads in joint replacement surgery and trauma surgery. The present study tries to test the usefulness of computer-assisted orthopedic surgery system

(CAOSS) in the development of mental navigation of the surgical trainee in 3-D space for common procedures like dynamic hip screws (DHSs). The study is initially used to train orthopedic trainees in placement of DHS guidewire and see the improvement in their performance after training on computer-assisted orthopedic training system for fracture fixation.

Computer-Assisted Orthopedic Training System

We use the CAOS system developed by Simulation and Visualization research group of which earlier versions have been in use since 1992.[9] The system is a fluoroscopy-based navigation system which combines intraoperative fluoroscopy-based imaging using conventional c-arm technology with freehand surgical navigation principles.[10] Optoelectronic markers are placed on the surgical tools as well as onto a firm bony reference point on the femur model. An initial precalibration procedure using the fluoroscope is performed through a tracked radiopaque spider. Using polaris tracking system, CAOS allows real-time image-interactive navigation of the surgical tools with respect to the 2 preacquired radiographic images. The system does not need to acquire additional radiographic images during the surgery. The computer also allows noncontact measurement of precise angles and depth of surgical tool penetration of bone (FIGURE 1 and FIGURE 2).

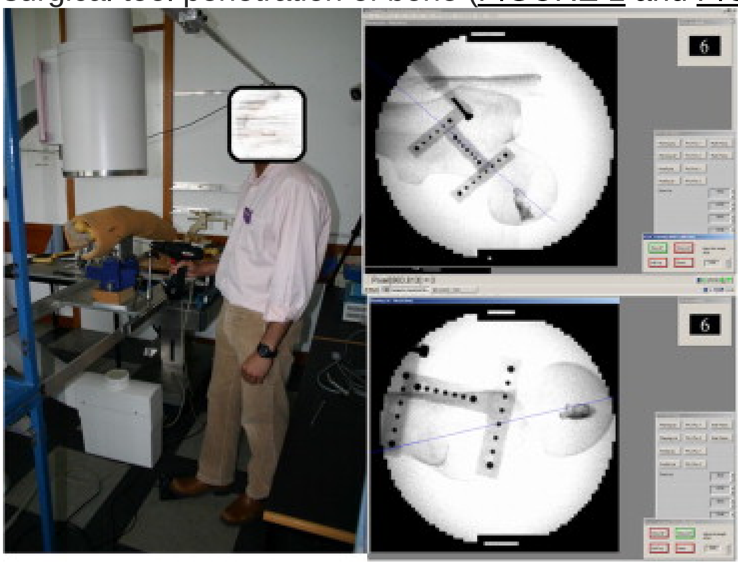

FIGURE 1.
CAOS setup and initial x-ray images.

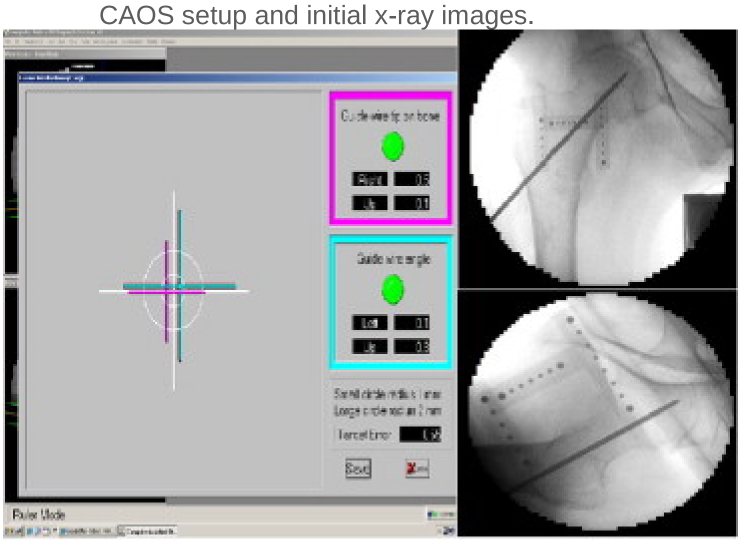

FIGURE 2.
Computer-screen and x-ray images during training.

Use of CAOSs in the Training of Placement of Guidewire for DHSs

Guidewire placement of DHS is one of the most crucial step in hip fracture fixation. Most of the time, junior orthopedic trainees, who have less experience in 3-D navigation of instruments using 2-D images, perform this procedure.

CAOS system uses a 2 image technique for the registration of bone and nail and c-arm calibration. Two-images anteroposterior and lateral views are taken by the image intensifier. These images contain the phantom markers and the proximal part of the femur. The femur is then marked and the desired trajectory of the DHS guidewire decided. The CAOSs guides the guidewire to correct orientation and position in the training mode.

Methods

The study was designed to include junior orthopedic trainees from the local hospital. All the junior surgical trainees who had not performed any DHS fixation and had no previous exposure to COAS training system were included in the study.

The trainees were randomly divided into 2 groups.

> *Group 1*: Initial part of the study involved the use of conventional CAOS system to train this group of orthopedic trainees. This group was trained using the CAOSs system in the development of 3-D orientation using a 2-D image for the DHS insertion.
> *Group 2*: This group would have no exposure to such training.

The *control group* was made of equal number of trained orthopedic surgeons who routinely fix these fractures so that the scoring system can be validated and the 2 groups can be compared to 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.

Scoring System

The ability for precision, 3-D navigation and processing of virtual information to help in hand-eye coordination has never been used as a formal training tool. The assessment of such skills demands a scoring system, which can be reproducible as well as validated. There is no scoring system that can accurately assess the ability to navigate instruments in 3-D space using a c-arm image.

We devised our own scoring system based on using task analysis; this included time difference between each exposure, the change in 3-D coordinates with each exposure, and total number of exposures to finish the task.

The procedure was broadly divided into 2 tasks:-

1 Navigation in 3-D space.
2 Drilling and putting the DHS guidewire at the desired position.

These 2 tasks were further divided into smaller subtasks and the candidate was scored in of these subtasks. The candidates were assessed using various parameters, these included the following:

3-D navigation

1 Time to align the guidewire in anteroposterior and lateral views
2 Number of entry points made
3 Number of exposures

Putting the guidewire at the desired position

1 Slipping of drill bit while trying to drill
2 Distance of the guidewire from the desired position at the entry, middle, and tip
3 Accuracy of measurement of the screw
4 Time taken

All these parameters were given weightage depending upon the importance of the step. The trainee is scored according to these parameters with a maximum score of 100.

Weightage of marks for each step (50% marks for each task)

1 Time to centering at the desired entry point (5 minutes given) then 1 mark is deducted for every 30 seconds extra taken (10% marks).
2 Number of exposure (5 allowed) then 1 mark is deducted for every extra exposure (20% marks).
3 Improvement with each exposure; 1 mark is deducted for every deviation (20% marks).
4 Slipping attempts (−1 mark for each slip) (20% marks).
5 Hole drilled with accuracy (−1 mark for 0.5 mm deviation from center of the hole) (5%marks).
6 Screw inserted with accuracy (10% marks); 5 mark is deducted for every 5 mm oversize/undersize of screw.
7 Time taken 20% marks (8 minutes allowed) 1 mark is deducted for every 30 seconds beyond 8 minutes. This time is subdivided into 2 tasks: 5 minutes for the first task and 3 minutes for the second task.

The scoring was validated using senior trainees who perform this procedure on the training system and scoring them using our scoring system. There was a consistency in the scores achieved by the senior trainees when performing this procedure on the system. The scoring system was validated and time was calculated after using the 6 trained orthopedic surgeons to perform the putting of the DHS guidewire at the desired position and calculate their average timing to devise the scores for each subset.

Results

The results were analyzed using a statistical application SPSS version 16 and tested for the statistical difference in the improvement of the mental navigation of instruments after training with the CAOSs. The trainees were assessed based on the time consumed along with the number of images taken to complete the DHS guidewire placement and also the accuracy of the procedure. The assessors had no prior knowledge of the prior training of the residents when they assessed the results and thus were blinded when assessing the scores.

Demographics

Twelve subjects (aged 23-34 years) who satisfied the inclusion criteria and agreed to participate were included in the study. There were 10 men and 2 women. All were junior orthopedic trainees.

Scores

There was a significant decrease in all the parameters in the first group (training) compared with group 2.

The number of exposures were 10.1 (mean) in the training group for guidewire placement compared with 37.4 (mean) in the second group.

There was an overall decrease in all the parameters and the mean score increased from 36.7 to 73.1 in the training group and this was statistically significant using chi-square test (p-value 0.03).

There was a gradual improvement of the scores when the trainees were routinely practising on the training system.

Discussion

This paper highlights that simulation is effective in reducing the time to gain a certain level of surgical skills of junior orthopedic trainees for fracture fixation. The trainee is involved in multiple steps, including 3-D navigation using 2-D fluoroscopy images. The improvement in the scores in the training group shows the usefulness of this system as an important training tool.[8] The scoring system was used to try and give participants formative feedback on their performance. This system helps trainee practice these complex fractures in a relatively stress-free environment without any additional x-ray exposures. This is of utmost importance where more and more junior trainees are spending less time in theater and have less exposure to hands-on training by senior surgeons in theater. The system provides results and scores with which the surgeon and trainee can readily identify and improve on subtasks within the particular surgery.

There is an increased need for the training tools in the orthopedic system. With the decreasing theater times and less exposure of the surgical trainee to the operative procedures, it is of utmost importance that the basic skills of orthopedics can be learnt in a nonthreatening and more relaxing non-OR environment. Thus, we wanted to create a simulator that could be used frequently, and could be accessible from a surgical trainee's own work environment, thus facilitating repetitive practice at times convenient to the trainee. At the moment, no such training system is available for fracture fixation.

We understand that the number of the subjects in the study are low but it still demonstrates that as the simulation system improves the accuracy and timing in junior orthopedic trainees. We are working on further trials using distal locking of femoral nails and cannulated screws as a template.

The system in its present format uses generic anatomical data on an artificial bone but the system is being further developed to include patient specific data and x-rays and the system is also being tried for fixing difficult scenarios such as elbow and pelvic fractures.

Conclusion

This paper presents a CAOSs training system for fracture fixation. The participants in each group felt that the training system was helpful in training of the fracture fixation. The improvement in the scores in the training group supports the argument for this system to be used more routinely for training of junior orthopedic trainees to fracture fixation.

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