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TRADITIONAL TRAINING VERSUS VIRTUAL REALITY AND HAPTIC ENABLED SIMULATION TRAINING FOR POSTERIOR CERVICAL SCREW PLACEMENT

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ABSTRACT

Objective: Simulation-based training is a technique, which evokes or replicates substantial aspects of the real world in a fully interactive fashion and replaces and amplifies real experiences with guided ones, which are generally immersive.

Materials and Methods: Twenty-five junior surgeons (20 orthopedic, 5 neurosurgeon) who were not involved in previous posterior cervical spine instrumentation participated in this study. Before the procedures, all surgeons received 2-hour lecture about cervical spine anatomy and screw insertion techniques. Group 1 (10 surgeons) underwent virtual reality simulation with haptic feedback for 20 min, group 2 (15 surgeons) were attended video sessions with experienced surgeons for 20 min for posterior cervical instrumentation training. After, all junior surgeons applied C1-2 screw, C3-4-5 lateral mass screws, and C6-7 cervical pedicle screws to saw bones. All saw bones underwent computerized tomography (CT) imaging and a blinded radiologist reviewed the CT images.

Results: Group 1 applied 70 screws and group 2 applied 105 screws. Group 1 showed a 12% misplacement ratio, while group 2 showed a 19% misplacement ratio and 4% rate of a possible vertebral artery trace penetration (p=0.026).

Conclusion: According to the results acquired from this study, we observed a lower cervical spine screw misplacement ratio in those who trained with VR based haptic enabled simulation before performing cervical posterior instrumentation.

Keywords: spine, virtual reality, cervical, posterior instrumentation, screw placement

INTRODUCTION

Surgical complications cost lives, and the economic impact of only the annual 1 million training-related orthopedic complications is $5 billion per year. There is no standardization in surgical training worldwide, thus many complications can be related to insufficient training and practice. The measurement and assessment in medical education cannot be done objectively, as there are no standard metrics available. According to the reported studies, we tend to forget 80 percent of what we learn in three days, unfortunately. This information can also be considered in resident education and training because it is difficult for young surgeons to repeat what they learn[1-3].

Simulation is not a new invention thus pilots are training with simulators since the 1980s. The swift technological advances of the 21st century enable us to create portable, feasible and reachable virtual-reality simulators with tactile feedback to use in medical education[3-5]. Simulation-based training allows learning and relearning as often as needed to correct mistakes, enabling the trainee to perfect steps and fine-tune skills to optimize clinical outcomes. Moreover, the trainee has the advantage of being in a familiar environment and do not need to take days off and to travel, which means saving money and time[6-9].

Simulation by virtual reality (VR) in orthopaedic surgery and neurosurgery for educational, preoperative planning, and intraoperative utilization continues to improve with technological advances in computer processing[2,10]. VR utilizes a computer processing unit with a head-mounted display to provide visual and auditory cues coupled with haptics to provide immersive, multisensory experience with creation of touch, vibration, and motion[3-5]. In this study, we aimed to

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compare traditional training and VR based and haptic enabled simulation for posterior cervical screw placement to the saw bone. We hypothesized that VR based training will result in better outcomes in terms of screw placement.

MATERIALS AND METHODS

After İstinye University Clinical Research Ethics Committee approval (3/2022.K-33) we obtained written informed consent for participation from all participants. Twenty-five junior surgeons (20 orthopaedic surgeons, 5 neurosurgeons) who had no previous experience in posterior cervical spine instrumentation procedure were participated in the current study. Before the procedures, all surgeons received 2-hour lecture about cervical spine anatomy, C1-C2 lateral mass and cervical pedicle screw application methods by expert senior surgeons who have more than 20 years of spine surgery experience. Then the surgeons were randomly divided into two groups. Group 1 comprised 10 junior surgeons that underwent 20 minutes VR simulation with haptic feedback posterior cervical instrumentation training. Fifteen junior surgeons were in Group 2 who underwent 20 minutes video demonstration by experienced surgeons. Then both two groups applied C1-2 screw placement by Harm's technique[11], C3-4-5 lateral mass screw placement by Magerl's Technique[12] and C6-7 cervical pedicle screw placement by Abumi's technique[13] to the cervical spine saw bone.

Features of the VR System

The simulator software (*Noya Enterprise,* İstanbul, TURKEY) is able to run on a standard notebook that consisted of suitable graphic hardware. *Oculus Rift* (*Oculus VR*, Facebook Technologies, CA, USA) headset was used for VR display. *Touch* (*3D systems*, CA, USA) haptic device is used for tactile simulation (Figure 1). The simulation software simulated hard tissues like bone and soft tissues like fat, muscle, and skin (Figure 2). The haptic system was not used to enhance psychomotor skills, but it was used to create an immersive environment through the use of tactile feedback.

Sawbones (*Sawbones®,* WA, USA) represent normal bony and disc structure from occiput to C7 vertebrae. Sawbones were used in prone position that embedded to foam model holder. Surgeons can only able to see the posterior surface of the model. Screws and rods (*Stryker*, MI, USA) were implanted strictly by freehand method (Figure 3). Surgeons implanted the screws by himself without any instructions by senior surgeons.

Radiological Evaluation

All saw bones were sent to the radiology department and axial, sagittal and coronal computed tomography (CT) images were taken. An expert radiologist who was blinded to the study groups reviewed all CT images and recorded the numbers of pedicle screw misplacements (Figure 4). In the axial plane, malposition of the screws was graded as; grade 0 (G-0): Correct placement, grade 1 (G-1): Malposition by less than half screw diameter, grade 2 (G-2): malposition by more than half screw diameter. The direction of malposition was classified into four categories: Medial, lateral, superior and inferior[14]. For lateral mass screw positioning, the location of the screw in relation to the edge of the root foramen and to the facet joint was assessed[15].

Statistical Analysis

Statistical analysis was performed by using SPSS 25.0 (SPSS Inc., IBM, NY, USA). Chi-square test was used to compare frequencies and a p-value of <0.05 is considered as statistically significant.

RESULTS

The number of pedicle screws implanted were 70 in Group 1 and 105 in Group 2. The screw misplacement ratio was 12% in Group 1 and it was significantly higher in Group 2 with a ratio of 19% (p=0.026). Within the misplaced screws in Group 2, 4% of the screws were directly damaging the vertebral artery trace.

DISCUSSION

The most important finding of this study was observing a significantly lower cervical pedicle screw misplacement ratio in those who trained with VR based and haptic enabled simulation before performing posterior cervical screw placement. Our null hypothesis can be easily accepted that we observed a better screw placement in those who trained with VR simulation before applying cervical posterior screw placement. A recent systematic review which evaluated VR based training in spinal

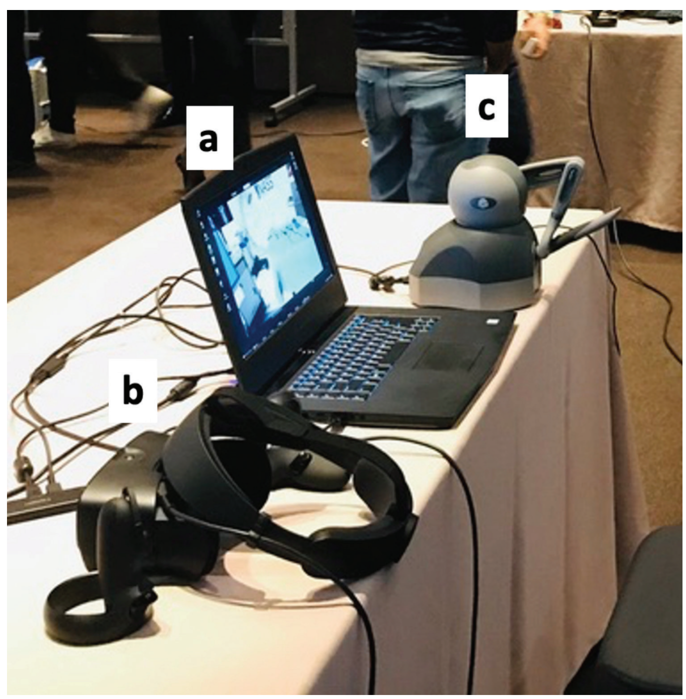

Figure 1. The devices used in simulation; (a) notebook, (b) headset for VR display, and (c) haptic device

VR: Virtual reality

surgery also remarked the importance of VR based training and recommended its use for training in spine surgery[9].

The main advantage of VR based training with haptic enabled simulation is providing an entirely immersive, multisensory operating room environment for training. A surgeon using this simulator can do pedicle screw, lateral mass screw placement in posterior cervical spine with unlimited repetition. In medicine, there is an ancient rule; "Primum non

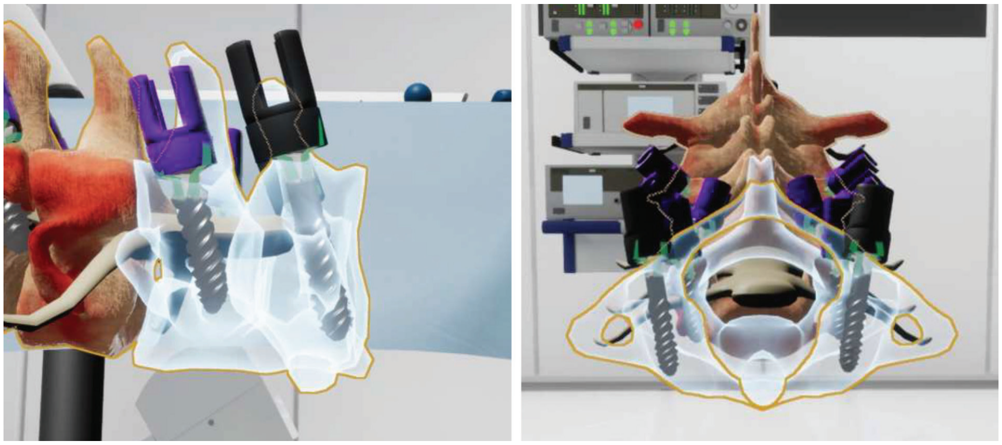

Figure 2. The screen shot image of cervical pedicle screw placement application

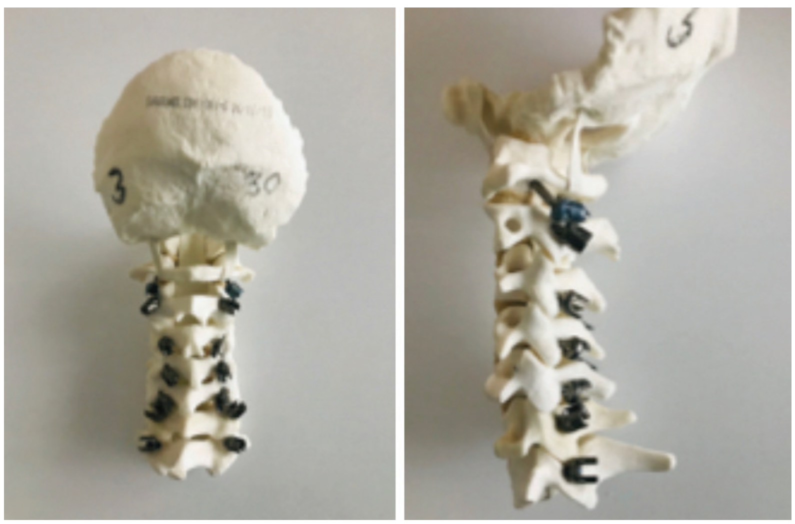

Figure 3. Applications of C1-2 screw with Harm's technique, C3-4-5 lateral mass screw with magerl technique and C6-7 cervical pedicle screws with Abumi technique to the saw bones without any instruction

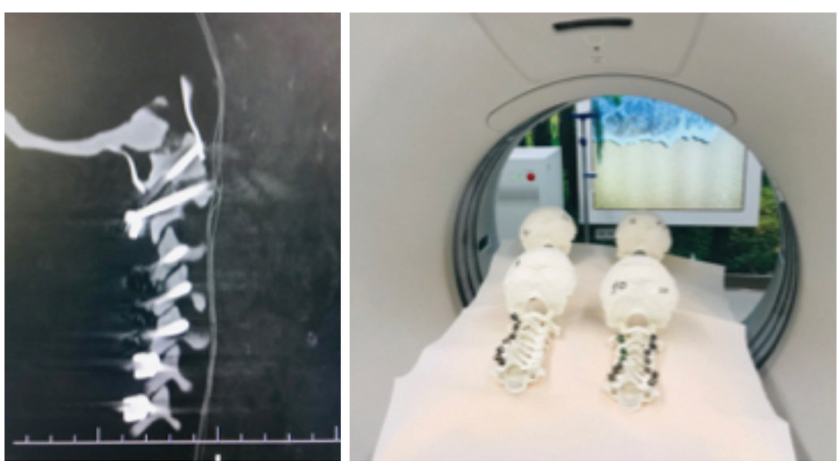

Figure 4. All saw bones underwent CT imaging and all screw pathways analyzed

CT: Computed tomography

nocere" meaning "First do no harm", while attending a patient. For this rule, it is essential to get the necessary training and experience. World Health Organization reports that 60% of surgical complications are due to not following surgical protocols. In order to not break the ancient rule, surgeons need to be trained intensively, and comprehensively. Medical professionals need to be trained so that they follow medical procedures step by step that need to be repeated many times to engrain it into their memories. We, therefore, need a practical; easy to reach and low-cost training method[10]. Professional development is an ongoing process in all walks of life. Unlike most, medical education and training not only requires vast amounts of knowledge but also interaction with patients. Briefly, education/training is the act and systemic instruction process of imparting or acquiring and validating particular competencies. These learned competencies are factual knowledge, know-how, operational skills, and overall attitude towards patient treatment.

Repetition is a crucial part of learning. It solidifies new skills, improves speed, increases confidence, and strengthens the connections in the brain. Most importantly, it draws attention to minor details. So, practice is the best way to solidify data that you need to keep in your mind and retrieve when required[11]. Reports of high complication rates in early adaptation in spine surgery may adversely steer established surgeons from performing these procedures. As the evidence grows for simulation training techniques in this field, it will reverse the current practice and training behaviors[2]. Those simulators should be commercially available and unique for every person. Simulation-based training allows learning and re-learning as often as needed to correct mistakes, enabling the trainee to perfect steps and fine-tune skills to optimize clinical outcomes. It is possible to filter and select trainees for further procedural competency-based training. Simulation-based medical education protects patients from unnecessary risks while developing health professionals' knowledge, skills, and attitudes. Future studies should attempt standardization of these simulation training techniques, clinical outcomes, supporting well conducted randomized trials of simulators use in spine surgery field. These outcomes should be combined with radiographic parameters with patient reported outcome measures.

Study Limitations

The main limitation of this study was evaluating a limited number of orthopaedic junior surgeon, so it is difficult to reach a higher level of evidence and statictical power. However, our study is the first study in the literature comparing VR training and traditional training in cervical spine posterior screw placement which can be considered as one of the most difficult procedure in spine surgery. In addition to that it is obvious that a better outcome due to an efficient training cannot be ignored. Therefore, our study can guide further studies and training centers to increase the quality of resident education.

CONCLUSION

In conclusion; according to the results acquired from this study, we observed a lower cervical spine screw misplacement ratio in those who trained with VR based haptic enabled simulation before performing cervical posterior instrumentation.

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Ufuk Aydınlı report that he affiliated with Noya Enterprise which financially sponsored to our study. These grant was used for simulator system, sawbones and computerized tomography.

Ethics

Ethics Committee Approval: Ethics committee approval was received for the study from İstinye University Clinical Research Ethics Committee (3/2022.K-33).

Informed Consent: Written informed consent was obtained from all participants.

Peer-review: Internally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: G.K.K., R.E.E., E.Y., Ç.Ö., U.A., Concept: G.K.K., R.E.E., E.Y., Ç.Ö., U.A., Design: G.K.K., R.E.E., E.Y., Ç.Ö., U.A., Data Collection or Processing: G.K.K., K.T., Y.Ç., C.E., E.Y., Ç.Ö., U.A., Analysis or Interpretation: G.K.K., K.T., Y.Ç., C.E., U.A., Literature Search: G.K.K., K.T., Y.Ç., U.A.,Writing: G.K.K., Y.Ç., U.A.

Conflict of Interest: The authors have no conflicts of interest to declare.

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