Training to acquire psychomotor skills for endoscopic endonasal surgery using a personal webcam trainer

Clinical article

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Object. Existing training methods for neuroendoscopic surgery have mainly emphasized the acquisition of anatomical knowledge and procedures for operating an endoscope and instruments. For laparoscopic surgery, various training systems have been developed to teach handling of an endoscope as well as the manipulation of instruments for speedy and precise endoscopic performance using both hands. In endoscopic endonasal surgery (EES), especially using a binostril approach to the skull base and intradural lesions, the learning of more meticulous manipulation of instruments is mandatory, and it may be necessary to develop another type of training method for acquiring psychomotor skills for EES. Authors of the present study developed an inexpensive, portable personal trainer using a webcam and objectively evaluated its utility.

Methods. Twenty-five neurosurgeons volunteered for this study and were divided into 2 groups, a novice group (19 neurosurgeons) and an experienced group (6 neurosurgeons). Before and after the exercises of set tasks with a webcam box trainer, the basic endoscopic skills of each participant were objectively assessed using the virtual reality simulator (LapSim) while executing 2 virtual tasks: grasping and instrument navigation. Scores for the following 11 performance variables were recorded: instrument time, instrument misses, instrument path length, and instrument angular path (all of which were measured in both hands), as well as tissue damage, max damage, and finally overall score. Instrument time was indicated as movement speed; instrument path length and instrument angular path as movement efficiency; and instrument misses, tissue damage, and max damage as movement precision.

Results. In the novice group, movement speed and efficiency were significantly improved after the training. In the experienced group, significant improvement was not shown in the majority of virtual tasks. Before the training, significantly greater movement speed and efficiency were demonstrated in the experienced group, but no difference in movement precision was shown between the 2 groups. After the training, no significant differences were shown between the 2 groups in the majority of the virtual tasks. Analysis revealed that the webcam trainer improved the basic skills of the novices, increasing movement speed and efficiency without sacrificing movement precision.

Conclusions. Novices using this unique webcam trainer showed improvement in psychomotor skills for EES. The authors believe that training in terms of basic endoscopic skills is meaningful and that the webcam training system can play a role in daily off-the-job training for EES.

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Keywords • endoscopic endonasal surgery • box trainer • webcam • psychomotor skills • surgical technique

Abbreviations used in this paper: EES = endoscopic endonasal surgery; VR = virtual reality.
training courses provide valuable opportunities to learn endoscopic anatomy with the guidance of well-established experienced surgeons. However, these courses are limited by time, cost, and availability, and the importance of acquiring fundamental endoscopic skills is not emphasized. Furthermore, the need for a psychomotor skills training system has been overlooked in the neurosurgical field. Along with the recent advance of extended EES for pituitary as well as skull base lesions, the minute bimanual manipulation of instruments with 2D visualization is becoming increasingly important. Neurosurgeons will be confronted with a steep learning curve in performing this type of surgery with the widely accepted minimally invasive methods. We report our preliminary evaluation of training via a simple, inexpensive, personal training box with a webcam and objectively assess the utility of this device for mastering basic endoscopic skills.

Methods

Study Participants and Design

Twenty-five neurosurgeons were enrolled as participants in this study. They were divided into 2 groups according to their clinical experience in endoscopic surgery. The novice group (19 neurosurgeons) had not experienced operations using either a rigid or a flexible endoscope and had not taken any skill development courses. The experienced group (6 neurosurgeons) had more than 3 years of experience with neuroendoscopic surgery. None of the participants had used a computer-based endoscopic simulator in the past. First, the basic skills of the volunteers were evaluated using the VR simulator (LapSim). Next, the neurosurgeons performed training tasks with a webcam training box, and then skills were reassessed on the VR simulator using the same exercises as those performed before the training.

Webcam Endoscopic Box Trainer

We constructed the box trainer mainly out of a webcam (Live! Cam Socialize HD [high definition] AF [auto-focus] webcam, Creative Technology, Ltd.), a Windows XP-based laptop computer, a flexible arm to mount the webcam, and acrylic boards. The dimensions were 21 x 20 x 25 cm. The training box had 2 holes covered by pierced rubber membranes that were set approximately 25 mm apart, simulating adult human nostrils. The webcam was placed at the level of the left hole of the training box, which was modeled on an actual endoscope inserted in the patient’s right nostril (Fig. 1A and B). The operative
depth varied from 8 to 15 cm after positioning a mounting base for tasks, and this depth was based on a model used in a previous report. Grasping forceps designed for EES were used as instruments for this trainer. Neurosurgeons were asked to execute 2 basic tasks for 15 minutes each, including a peg transfer (Task 1) and instrument navigation (Task 2). In Task 1, a participant lifted a doughnut-shaped rubber ring with the grasping forceps using the nondominant hand and transferred the ring in midair to the dominant hand and placed it on another peg (Fig. 1C). This task was repeated for 10 minutes. Task 2 involved alternately moving 2 forceps in a precise manner to touch with the tips of the forceps the heads of needles mounted on the base (Fig. 1D). We carefully checked to see if participants watched the personal computer monitor and not the tip of the instruments under direct vision during the webcam training.

**Evaluation of Basic Skills**

Each neurosurgeon’s performance was objectively evaluated with the VR simulator before and after training by using a webcam box trainer (Fig. 1E). The neurosurgeons were required to perform the simple virtual tasks including grasping and instrument navigation. They repeated each task 3 times, and the scores for the following 11 performance variables were recorded: instrument time (total time spent performing VR tasks for each hand), instrument misses (number of mistakes on the right and left side in the forceps operation), instrument path length (total distance of travel in the forceps operation for each hand), and instrument angular path (total angle variation of the forceps operation for each hand), all of which were measured in both hands, as well as tissue damage (number of instances of hitting untouchable tissues, with fewer instances leading to a higher score), max damage (maximum distance of deviation, with less deviation leading to a high score), and overall score. For each task, the perfect score was 100. We indicated instrument time as movement speed; instrument path length and instrument angular path as movement efficiency; and instrument misses, tissue damage, and max damage as movement precision. The overall score and the score for each virtual task were recorded.

The data were statistically analyzed using a paired t-test to assess differences in performance before and after the training. A value of p < 0.05 was considered statistically significant (SPSS Statistics, version 20, IBM, Inc.).

**Results**

All of the neurosurgeons were right-handed males with a mean age of 32.3 ± 4.1 years (range 27–42 years). The novice group included 19 neurosurgeons with a mean age of 30.8 ± 3.1 years and mean postgraduate years of 6.4 ± 2.7 years. The experienced group consisted of 6 neurosurgeons board-certified by the Japan Neurosurgical Society with a mean age of 36.8 ± 3.8 years and mean postgraduate years of 12.2 ± 4.2 years. The age and postgraduate years of the neurosurgeons in the experienced group were significantly higher than those in the novice group. We estimated the change in performance before and after training with the webcam neuroendoscopic box trainer in both the novice and experienced groups (Table 1).

<table>
<thead>
<tr>
<th>Performance Variable</th>
<th>Novice Group†</th>
<th>Experienced Group†</th>
<th>p Value‡</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NB</td>
<td>NA</td>
<td>NB-NA</td>
</tr>
<tr>
<td>instrument time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lt</td>
<td>46.4 ± 38.4</td>
<td>78.3 ± 30.7</td>
<td>81.3 ± 26.1</td>
</tr>
<tr>
<td>rt</td>
<td>39.5 ± 37.6</td>
<td>71.8 ± 28.9</td>
<td>70.6 ± 29.7</td>
</tr>
<tr>
<td>instrument misses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lt</td>
<td>98.3 ± 13.3</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>rt</td>
<td>98.3 ± 13.3</td>
<td>100</td>
<td>100</td>
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<tr>
<td>instrument path length</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lt</td>
<td>65.8 ± 34.8</td>
<td>86.1 ± 22.4</td>
<td>85.7 ± 25.6</td>
</tr>
<tr>
<td>rt</td>
<td>72.9 ± 34.9</td>
<td>89 ± 19.4</td>
<td>83.2 ± 28.4</td>
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<tr>
<td>instrument angular length</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lt</td>
<td>70 ± 35.8</td>
<td>93.8 ± 17</td>
<td>93.7 ± 13.8</td>
</tr>
<tr>
<td>rt</td>
<td>74.2 ± 34.9</td>
<td>88 ± 24</td>
<td>92.6 ± 15.8</td>
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<tr>
<td>tissue damage</td>
<td>72.1 ± 28.8</td>
<td>92.8 ± 9.4</td>
<td>92.2 ± 10.6</td>
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<tr>
<td>max damage</td>
<td>95.9 ± 16</td>
<td>99.6 ± 3.3</td>
<td>100</td>
</tr>
<tr>
<td>overall score</td>
<td>74.1 ± 20.5</td>
<td>90.3 ± 10.3</td>
<td>93.2 ± 7.4</td>
</tr>
</tbody>
</table>

* Maximum score = 100. Values expressed as the means ± standard deviations. Abbreviations: EA = experienced, after training; EB = experienced, before training; NA = novice, after training; NB = novice, before training; NS = not significant.
† Novice group consists of 19 neurosurgeons; experienced group consists of 6.
‡ Hyphen between abbreviated terms signifies “compared with”; for example, NB-NA = NB compared with NA.
other than instrument misses significantly improved after webcam box training, indicating that movement speed and efficiency were enhanced after training (Fig. 2 upper). No significant improvement in instrument misses suggested that the novices had manipulated instruments slowly and carefully. On the other hand, in the experienced group, significant improvement was demonstrated only in instrument path length (right hand) after training. In the virtual tasks in which movement precision was assessed, the experienced neurosurgeons attained a perfect score of 100 in instrument misses and max damage, both before and after training, which suggested a ceiling effect (Fig. 2 lower).

Before training, the mean performance scores in the experienced group were significantly superior to those in the novice group in all parameters except instrument misses and instrument path length in the right hand, indicating significantly greater movement speed and efficiency in the experienced group but a relatively small difference in movement precision between the 2 groups. This finding may suggest that novices operated the instruments carefully to avoid making big mistakes (Fig. 3 upper). After the training, the mean performance scores in the experienced group were equal or superior to those in the novice group in all performance variables; however, no significant difference was demonstrated between the 2 groups except for instrument angular length and overall score (Fig. 3 lower). These data suggest that the webcam box training improved the basic skills of the novices, increasing movement speed and efficiency without sacrificing movement precision.

**Discussion**

The 3D world is first perceived as a 2D image on the retinas through the eyes and is next reconstructed in the brain by integrating binocular and monocular cues. Binocular cues include convergence, accommodation, and binocular disparity, whereas monocular cues include motion parallax and pictorial cues such as occlusion or overlap, perspective, shading, relative size, and texture gradients. In endoscopic surgery, in a similar fashion, surgeons observe a 2D surgical field on a flat monitor.
However, experienced surgeons can actually perceive a 3D surgical field, because even under the 2D endoscopic conditions the brain can perceive a 3D image by integrating the monocular cues with touch confirmation. Furthermore, a comprehensive knowledge of endoscopic anatomy plays an important role in creating 3D images in the brain.

Novice endoscopic surgeons must acquire psychomotor skills; however, conventional on-the-job training has been difficult from ethical and medicolegal viewpoints and because of pressures to reduce resident work hours.\(^{15}\) Nowadays, various kinds of off-the-job training have been proposed and practiced, especially for laparoscopic surgery, including training using live animal models, cadaveric specimens, box trainers, and most recently a VR simulator. Training using both live animal models and cadaveric specimens has several advantages, although high costs and ethical issues are their major drawbacks.\(^{14}\) The availability of box trainers or video trainers has been shown to improve laparoscopic skills, translating them into improved operative performance; however, trainees cannot learn anatomy and advanced skills, and the evaluation of task execution is not objective.\(^{17}\) The VR simulator is well recognized as an effective tool for developing and objectively estimating endoscopic psychomotor skills,\(^{12,22}\) as some prospective randomized trials have documented.\(^{5,9,18}\)

As described above, the importance of training for learning basic laparoscopic skills has been discussed since the method was first introduced. In neuroendoscopic surgery, on the other hand, existing training methods are not directly aimed at the acquisition of fundamental endoscopic skills, probably because refined psychomotor skills would not be necessary under a condition that the azimuth angle, defined as the angle between the instrument and the optical axis of the endoscope, is nearly 0°.
in most neuroendoscopic solo surgeries through a single port. Furthermore, neurosurgeons continually practice microsurgical procedures under microscopic visualization, which is indeed a distorted 3D world. The recent advent of the endoscopic binostril approach to the skull base and pituitary regions seems to require more advanced psychomotor skills, because the manipulation and azimuth angles are both wider than in other kinds of neuroendoscopic surgery.

Various investigations have been conducted to develop training tools for EES, such as cadaveric dissection and real anatomical models. Recently, studies have described the availability of a training box for the dissection of Wistar rats\(^1\) and a sinus surgery trainer designed to simulate fundamental EES skills. The face, content, and construct validities of the VR simulator have been established, and the validity for the transfer of skills acquired on the simulator into live surgery has also been demonstrated. For these reasons, in the present study, we used the VR simulator for the objective assessment of basic endoscopic skills before and after EES training, as previous investigations had used it for the same purpose in laparoscopic training.\(^{10,12,17,22,23}\)

We developed a prototype of a box trainer for learning the psychomotor skills required for EES. We revealed that the training using this box trainer could improve psychomotor skills for novices. The box trainer is simple, inexpensive, portable, and personal, because a webcam and a laptop computer were used as a substitute for an endoscope and a display, respectively. It cost approximately $180, including $60 for a webcam and $100 for acrylic boards. This is the first report of a webcam trainer for EES, although authors of another report have described laparoscopic skill training using a webcam system. The webcam used in the present study provided smooth 720p high-definition-quality video capture and playback of up to 30 frames per second, having a built-in image sensor with 2 million pixels and auto focus capability. Only simple tasks were used for this box trainer; however, various types of task modules can be set in this training box to perform other exercises that mimic actual EES procedures, similar to the model that was developed by Malekzadeh et al.\(^11\) Of course, our prototype has some limitations. Image resolution and quality were poor as compared with an actual endoscope, and slight hysterisis of movement was noticed, although it did not hinder the execution of tasks. Note that the box trainer cannot provide learning of the sinonasal anatomy and real endoscopic navigation. The small sample size is the primary limitation of this study. Despite these issues, we propose that the webcam box trainer may adequately train novice surgeons in psychomotor skills and may provide a means for novices to acquire basic endoscopic skills to overcome the steep learning curve for EES procedures. Additionally, it may prove useful for other neuroendoscopic procedures.

Conclusions

We described a simple, inexpensive, mobile, personal box trainer using a webcam system for EES. The utility of this training device was objectively demonstrated, especially for novices, through the execution of virtual basic tasks using a VR simulator. The endoscopic endonasal binostril approach has been indicated for selected pituitary and ventral skull base pathologies as an alternative to conventional skull base approaches and requires more advanced psychomotor skills. This webcam training box can help novice neurosurgeons learn the basic endoscopic procedures during daily off-the-job training. Given the widespread use of minimally invasive surgical techniques, we believe that it will be necessary to establish a validated and standardized training system to aid in the acquisition of endoscopic psychomotor skills.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Fujimoto. Acquisition of data: Fujimoto, Hirayama. Analysis and interpretation of data: Hirayama. Drafting the article: Fujimoto, Hirayama. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Fujimoto. Statistical analysis: Hirayama. Study supervision: Fujimoto.

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