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Operating Room Performance Improves after Proficiency-Based Virtual Reality Cataract Surgery Training

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Purpose: To investigate the effect of virtual reality proficiency-based training on actual cataract surgery performance. The secondary purpose of the study was to define which surgeons benefit from virtual reality training.

Design: Multicenter masked clinical trial.

Participants: Eighteen cataract surgeons with different levels of experience.

Methods: Cataract surgical training on a virtual reality simulator (EyeSi) until a proficiency-based test was passed.

Main Outcome Measures: Technical performance in the operating room (OR) assessed by 3 independent, masked raters using a previously validated task-specific assessment tool for cataract surgery (Objective Structured Assessment of Cataract Surgical Skill). Three surgeries before and 3 surgeries after the virtual reality training were video-recorded, anonymized, and presented to the raters in random order.

Results: Novices (non−independently operating surgeons) and surgeons having performed fewer than 75 independent cataract surgeries showed significant improvements in the OR—32% and 38%, respectively—after virtual reality training ($P = 0.008$ and $P = 0.018$). More experienced cataract surgeons did not benefit from simulator training. The reliability of the assessments was high with a generalizability coefficient of 0.92 and 0.86 before and after the virtual reality training, respectively.

Conclusions: Clinically relevant cataract surgical skills can be improved by proficiency-based training on a virtual reality simulator. Novices as well as surgeons with an intermediate level of experience showed improvement in OR performance score. *Ophthalmology 2016;■:1−8 © 2016 by the American Academy of Ophthalmology*

Complication rates in operations are affected by the experience and surgical skills of the surgeon.[1−3] Ideally, simulation-based training of surgical skills improves performance in the operating room and thereby diminishes the complication rate related to inexperience.[4,5] Yet, the effect of simulation-based training on operating room performance has never been investigated prospectively for the entire cataract surgical procedure.

By using proficiency-based training, learners train to a predefined, evidence-based benchmark (i.e., proficiency level) measured by valid performance metrics. This approach has proven to be one of the most effective ways to train technical skills[6] and is continually implemented in ophthalmology training programs.[7] In contrast to repetition- and time-based training, proficiency-based training ensures that only surgeons who meet the defined benchmark progress in the training program, and eventually operate on patients.[4]

Different training models exist for the training of cataract surgical skills.[8] One of the advantages of using virtual reality simulators is that performance metrics are embedded in the software, enabling continuous performance feedback and allowing feasible implementation of proficiency-based training.[9] The EyeSi simulator (VRmagic, Mannheim, Germany), is the most commonly used virtual reality simulator in ophthalmic surgery, including cataract surgery, and its performance metrics have previously been investigated and an evidence-based proficiency level has been established.[10]

Nevertheless, our knowledge on transfer of skills from a simulated environment to the operating room is still limited.[8] Previous retrospective studies and 1 case series with 3 trainees have shown an effect of the implementation of standardized cataract surgical training programs, including virtual reality training, on complication rates or time to complete surgery.[11−15] However, the retrospective design—not controlling for other variables that may have influenced trainees' performance—and divergent results call for prospective studies investigating the effect of virtual reality training on operating room performance.[16] Whereas the focus has mainly been on surgical trainees at the beginning of their learning curve, the question of which training level is appropriate to benefit from the training remains unanswered.[17]

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The aim of this study was to investigate the effect of proficiency-based virtual reality training on cataract surgical skill in the operating room for surgeons with different levels of experience.

Methods

This study was conducted as a multicenter clinical trial with masking of both raters and outcome assessors. The Ethics Committee of the Capital Region of Denmark ruled that approval was not required for this study (protocol no. H-6-2014-011). The study adheres to the tenets of the Declaration of Helsinki and is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines for simulation research.[18]

Participants

From April 1, 2014, to March 11, 2015, 19 cataract surgeons from Denmark were included in the study. We intended to include cataract surgeons representing all experience levels, including surgeons not yet operating independently (i.e., performing only single steps of the cataract surgery). Because of a limited cohort of ophthalmologists undergoing cataract surgical training in Denmark, we invited all surgeons having performed fewer than 1000 surgeries to participate in the study. Eligible participants were identified by contacting chief consultants and/or cataract surgical program directors at all ophthalmology departments in Denmark. From a cohort of 22, 2 did not respond to the invitation and 4 did not find time to participate in the study. Furthermore, 3 expert surgeons (defined as having performed >1000 surgeries) were included in the study. In total, 19 cataract surgeons, employed at 9 different ophthalmology departments and 2 private clinics in Denmark, were enrolled into the study. We divided the surgeons into 4 groups according to experience level: novices, the group of surgeons who did not yet operate independently but performed only steps of the cataract surgical procedure (0 independent operations at time of enrollment in the study); intermediates, defined as surgeons on the steeper part of the learning curve[19] (1−75 independent operations); experienced surgeons (76−999 operations); and expert surgeons (≥1000 operations). All participants gave oral and written consent before inclusion and completed a questionnaire regarding demographic data and surgical experience.

Simulator Training

The virtual reality simulator training was carried out at the Simulation Centre at Rigshospitalet (Copenhagen Academy of Medical Education and Simulation). The cataract (phacoemulsification) interface on the VRmagic EyeSi simulator, version 2.8.10, was used for the study. All participants were given a 10-minute introduction to the simulator. A previously established performance test with evidence of validity was used for the proficiency-based training[10]: All participants trained on the simulator until they achieved a predefined pass/fail score of 600 points (of a maximum of 700 points) in 2 consecutive sessions. This pass/fail level was based on previous study results[10] and evidence indicating that deliberate "overtraining" leads to enhanced skill retention.[6] During training, 1 author (A.S.S.T.) gave instructions to all participants. Table 1 shows details on the proficiency-based training, including settings on the simulator.

Surgical Procedure

The participants performed 3 consecutive phacoemulsification surgeries immediately before and after the training intervention (Fig 1). They were only allowed to operate on uncomplicated cataract cases, defined as follows: (1) being performed under local anesthesia, (2) patient >60 years of age, (3) preoperative best-corrected visual acuity >1/60 (measured using a standard Snellen chart at 6 meters' distance). Age and visual acuity of the patients were noted by the study participants and disclosed to the primary investigator. Furthermore, the timing of the operations was cross-checked to ensure that the surgeons did not select specific operations based on their own preferences to be included in the study. The novices informed the primary investigator about which surgical steps had been performed by their supervisor. All phacoemulsification techniques (including divide-and-conquer and phaco-chop techniques) were accepted. The participants were not allowed to operate on patients while they underwent training on the simulator. Exclusion criteria were as follows: (1) more than 2 weeks between operations and training intervention, and (2) inability to provide the 6 video recordings of performed operations.

Data Anonymization and Masking

The surgeries were video-recorded and thereafter anonymized regarding the identity of both the patient and the surgeon. This was done by cropping the recordings before and after performance of the actual procedure in addition to removing logos, person identifiable data, and sound using Final Cut Pro video editing software version 7 (Apple, Inc, Cupertino, CA). The videos were presented to 3 masked cataract surgeons in a random order through a secured web-based video-rating software.[20] The outcome assessors were also masked to the identity of the surgeons until data were collected and saved in a database.

Outcome Measures

The primary outcome measure was technical performance, measured by the Objective Structured Assessment of Cataract Surgical Skill (OSACSS) rating scale.[21] The rating scale consists of task-specific items and global indices, which are rated from 1 point ("inadequately performed") to 5 points ("well performed"). The first item, concerning draping, was omitted because the surgical assistant usually performs this step of the procedure in Denmark. Global indices were rated but not included in the final assessment score to make comparison between non−independently operating surgeons and independently operating surgeons possible. Thus, the assessment of technical performance included 13 task-specific items, which were rated using the original 5-point rating scale (Fig 2). After recoding the scores from 0 to 4, the final assessment scale ranged from 0 to 52 points, with 52 points representing superior performance. Three raters evaluated all videos independently. Before the initiation of the study, raters were trained to ensure a standardized assessment and to avoid rater errors. Specifically for the novices, steps performed by their supervisor were adjusted to the lowest score ("inadequately performed") post hoc by the primary investigator.

Reliability

Generalizability theory, a statistical method developed by Cronbach et al, was used to analyze the reliability of the OSACSS scores[22]. We used a fully crossed design for every factor in the assessment, meaning that all surgeons performed 3 procedures before and after virtual reality training, and all 3 raters evaluated all procedures. This study design made it possible for us to investigate different sources of bias, including observer bias. Another possible bias would be the influence of the novice surgeons' natural learning curve on the estimated size effect, that is, the performance improvement from case to case leading to an improvement in performance score not caused by the virtual reality training itself. To attribute an observed effect to the

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