Can virtual reality surgical simulator improve the function of the non-dominant hand in ophthalmic surgeons?

Rasha M Eltanamly, Hany Elmekawey, Maha M Youssef, Lameece M Hassan

Purpose: Phacoemulsification surgery requires the use of both hands; however, some surgeons may not be comfortable using their non-dominant hand, especially in critical steps such as chopping. This work aims at assessing whether a virtual reality simulator can help cataract surgeons train their non-dominant hand using the capsulorhexis module. Methods: This was a prospective observational study including thirty ophthalmic surgeons; none of them had previous training on the EyeSi surgical simulator. Twenty-three were experienced, and seven were intermediate surgeons. Surgeons were asked to perform capsulorhexis three times using their dominant hand and then using their non-dominant hand. A performance score based on efficiency, target achievement, instrument handling, and tissue treatment was calculated by the simulator. Results: A significant improvement in the score of surgeons using their non-dominant hand from the first trial (69.57 ± 18.9) to the third trial (84.9 ± 9.2) (P < 0.001) was found, whereas such improvement was not noted with the dominant hand (P = 0.12). Twenty-six surgeons managed to reach 90% of the mean score achieved by dominant hand by using their non-dominant hand, 11 (36.7%) from the first trial, seven (23.3%) from the second, and eight (26.7%) from the third. Conclusion: Cataract surgeons showed significant improvement in the scores of their non-dominant hands with simulator training. Thus, it is possible to safely train non-dominant hands for difficult tasks away from the operating room, which would be a fruitful addition to residency training programs.

Key words: Capsulorhexis, non-dominant hand, simulator training

Cataract surgery is one of the most commonly performed surgeries worldwide. The phacoemulsification technique for cataract extraction is associated with a significant learning curve. Complication rates are markedly higher for trainee surgeons but decline with experience.\[1\]

Phacoemulsification is a surgery requiring the use of both hands, and some surgeons may not be comfortable using their non-dominant hand while performing some of its critical steps. In addition, certain phacoemulsification techniques such as opting to sit at the head end for the left eye and performing surgery with the left hand (non-dominant hand) were found to be more successful. The ultrasound handpiece is held in the non-dominant hand and becomes a passive instrument in the central part of the capsular bag, while the chopper is held by the dominant hand and actively used for maneuvering; resulting in the use of less ultrasound energy for nuclear management.\[2,3\]

However, there are concerns about the difficulty in learning such techniques as it demands the skill of the non-dominant hand, and practicing in the operating theater may pose risks to the patient.

Simulator-based training is becoming a fundamental part of ophthalmic training. Many tools are currently available for training and assessment in phacoemulsification surgery outside the theater. Training on virtual reality simulators (VRSs) is now often used as an adjunct to microsurgical skills courses.\[4\]

This work aims at assessing whether VRSs can help cataract surgeons train their non-dominant hand using the capsulorhexis module, allowing them more dexterity when operating on patients especially when managing difficult scenarios.

Methods

This is a prospective observational study that adheres to the tenants of the Declaration of Helsinki.

Thirty cataract surgeons were included in this study; surgeons were excluded if they had previous training on any ophthalmic surgical simulator. They were recruited through personal communication.

a) Methods

Surgeons were divided into two groups: intermediate experience (performed 50–200 surgeries prior to the study) and experienced (>500 surgeries) surgeons. We recruited all the intermediate and experienced surgeons, without previous experience with simulator training in our department, resulting in a convenience sample. The Eyesi surgical simulator (VRmagic software version 2.9, Mannheim, Germany) [Fig. 1] was used in this study.

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Cite this article as: Eltanamly RM, Elmekawey H, Youssef MM, Hassan LM. Can virtual reality surgical simulator improve the function of the non-dominant hand in ophthalmic surgeons?. Indian J Ophthalmol 2022;70:1795-9.
The cataract head was used. The simulator consists of a model eye connected to a computer. Probes are inserted into the model head, and cameras inside the eye detect the movement of the probes. A virtual image is created on the computer. The virtual image is projected onto two oculars, creating a binocular animated virtual image of the anterior segment (with depth perception). The image is also projected onto a screen. Several manipulations and procedure-specific modules are available in the simulator. A consultant trainer gave all surgeons a standardized simulator introduction. Each candidate was also given instructions on the set-up, including microscope adjustment, seating, positioning, and foot-pedal use.

**b) Simulator Training**

For this study, the capsulorhexis (level 1) module was chosen as it was found to be construct valid (can differentiate between the levels of experience: novice, intermediate, and experienced) and showed a statistically significant discriminative ability, thus allowing differentiation between surgeons of different levels of surgical experience and assessment of performance.

According to Thomson et al.,[6] the five trials were needed to ensure the highest level of validity in assessment in multiple modules available in the simulator, including the capsulorhexis module. In addition, capsulorhexis and divide-and-conquer modules were previously rated the two most difficult steps in phacoemulsification training.[7] The surgeon had to create a flap of the anterior capsule with a cystotome and create a capsulorhexis using forceps. Permanent viscoelastic was used for filling the eye model throughout all trials.

After a few trials (2–3) on the simulator to eliminate the learning effect and to make the surgeons more acquainted with the machine, the surgeon was asked to perform three trials of capsulorhexis (all of equal difficulty) with his dominant hand. Then, the surgeon would proceed to perform the same step using his non-dominant hand for three trials. Even if the surgeon achieved 90% of the mean achieved by the dominant hand on their first trial, they continued with the second and third to demonstrate consistency.

A performance score ranging 0–100 points was calculated by the simulator for each trial. The score was based on the...
efficiency of the procedure, target achievement, instrument handling, and tissue treatment [Fig. 1].

Improvement in performance of non-dominant hand was assessed by measuring the significance of the change in the mean test score throughout the trials and the number of surgeons that were able to achieve 90% of their mean test score of dominant hand after the third trial of their non-dominant hand.

Statistical methods

Data were coded and entered using the statistical package SPSS (Statistical Package for the Social Science) version 22. Normal data were summarized using mean and standard deviation. Median, minimum, and maximum were used to summarize non-normal quantitative data, while frequency (count) and relative frequency (percentage) were used for categorical data. Comparisons between intermediate and experienced surgeons were done using unpaired t test in normally distributed variables, while the non-parametric Mann–Whitney test was used for non-normally distributed quantitative variables.[9] For comparison of serial measurements within each group, repeated-measures ANOVA was used in normally distributed quantitative variables, while the non-parametric Wilcoxon signed-rank test was used for non-normally distributed quantitative variables.[9] P < 0.05 was considered statistically significant. When comparing categorical data, we used Chi-squared test or Fisher’s exact test when dealing with groups with less than five cases.[10] Tests were two-sided, and P was corrected for multiple comparisons.

Results

Thirty cataract surgeons were recruited in this study; 23 were experienced, and only seven were intermediate surgeons. There were 26 right-handed (87.7%) and 4 left-handed surgeons (13.3%). The mean of the global score of each trial by the dominant and non-dominant hand for all surgeons was calculated and the results are shown in Table 1.

There was a significant improvement in the performance of surgeons using their non-dominant hand from first trial, 69.57 ± (18.9) to third trial 84.9 ± (9.2) (P < 0.001), whereas such improvement was not noted with the dominant hand (P = 0.12).

When comparing performance among intermediate and experienced surgeons throughout the six trials, the statistically significant difference in the mean test score was revealed only in the second trial of the non-dominant hand (P = 0.02) [Table 2].

Experienced surgeons showed a significant increase in the mean test score of their non-dominant hand with simulator training throughout the trials (P < 0.001). A significant improvement was also found when comparing each trial with the previous one (P = 0.006). In contrast, these results were not found to be significant in intermediate surgeons, although there was an improvement in their mean score from 58.4 in the first trial to 81 in the third trial.

We assessed the number of trials needed for the non-dominant hand to reach 90% of the mean achieved by the dominant hand. Twenty-six surgeons managed to reach 90% of their mean score: 11 (36.7%) achieved it from the first trial, seven (23.3%) from the second trial, and eight (26.7%) from the third trial. The mean number of trials for those surgeons was 1.88 ± 0.86.

The 11 surgeons who achieved 90% of the mean score of their dominant hand in the first trial with their non-dominant hand included seven experienced and four intermediate surgeons. When analyzing the improvement rate of those surgeons from the first to the third trial, most remained consistent throughout the trials with an insignificant change (average rate of improvement was 0.36%).

Four (13.3%) surgeons could not achieve the 90% score of their dominant hand.

When comparing left-handed surgeons to right-handed ones, left-handed surgeons were able to achieve 90% of their left-hand score using their right hand after one trial in 75%. However, right-handed surgeons achieved 90% of their right-hand score using the left hand after one trial in 30.8%. The difference was statistically insignificant (P = 0.38).

Discussion

This study aimed at assessing whether VRSs can help cataract surgeons train their non-dominant hand. Surgeons are normally familiar with using their non-dominant hand during steps such as irrigation/aspiration and nuclear fracture. However, this study aimed at assessing a more complex step, the capsulorhexis. The capsulorhexis module we chose was previously validated,[5,6,11] suggesting that this simulator when used for ophthalmic training is quite realistic.
According to our study, the test scores achieved by surgeons using the non-dominant hand can be improved significantly with training on the simulator. Experienced surgeons showed no improvement with their dominant hand, which may be expected as the experienced surgeons are already familiar with the surgical procedure and have reached the plateau phase of their learning curve; thus, their scores remained similar using the dominant hand after their introduction to the machine. They are thus most likely to benefit from training of their non-dominant hand.

Training of the non-dominant hand may not be feasible in a real-life operating room as it would be considered unsafe to patients and therefore unethical. Thus, surgical simulators are crucial in training the non-dominant hand.[10]

Some trials investigated the effect of new surgical simulation training on surgery time and complication rates in an operating room setting. Rogers et al. found a significant decrease in complication rates, from 7.2% in the pre-intervention cohort to 3.8% in the post-intervention cohort.[11] Belyea et al. (a retrospective study) found a significant decrease in phacoemulsification time and power use, but with a non-significant decrease in complication rate in phacoemulsification surgery (without dividing the procedure into specific steps).[14]

In our study, twenty-six (86.7%) surgeons reached 90% of the mean test score of their dominant hand by the third trial. We noted a definite improvement in the test score of the non-dominant hand in all surgeons (P < 0.001) and with experienced surgeons (P < 0.001). There was a trend of improvement in intermediate surgeons, but it did not reach significance (P = 0.1); this can be explained by the fact that the number of less-experienced surgeons in this study was small as all our residents have the virtual reality simulator training incorporated in their teaching program.

We are aware of a study by Gonzalez et al.[15] that assessed the improvement of non-dominant hand on the simulator; they found significant improvement of both dominant and non-dominant hand. However, their study included only 14 surgeons, and only three of them were attending physicians.

Although in our study, we started with the trials of the dominant hand before those of the non-dominant hand, allowing increased acquaintance with the simulator module and possibly creating bias, we believe that most surgeons are more accustomed and thus more efficient in using their dominant hand. Thus, even if bias occurs due to increased acquaintance with the program, the discrepancy in experience between the dominant and non-dominant hand is still much greater.

We compared the results of right to left-handed surgeons and when they attained 90% score of their dominant hand. Three (75%) left-handed surgeons reached 90% performance in the first trial as compared to eight (30.8%) right-handed surgeons. All left-handed surgeons reached the 90% score, whereas four right-handed surgeons could not. This difference was not significant (P = 0.38) and can be explained by the naturally small sample size of left-handed surgeons. Moreover, some studies showed that left-handed surgeons performed better surgically and had fewer complications than right-handed ones[18] or are more trained on using their non-dominant hand in daily routine activities.

VRS training is a safe option for training residents and has been incorporated in many teaching hospitals. However, they are expensive and may not be available in all institutes. Akarra and Kuriakose[16] suggested using low-cost items available at homes, such as tomatoes, potatoes, and boiled eggs, with smartphones functioning as microscopes to safely and economically practice many phacoemulsification steps. This offers a great alternative if a VRS is not available or during lockdown measures. However, VRSs offer construct validity (the ability to reliably distinguish between novice and expert surgeons) for task allocation. They can also quantitatively assess the following training points: accuracy (capsulorhexis decentration and regularity), efficiency (time from the first interaction to completion), injury (incision stress, corneal touch), and target achievement (percentage of goal and tracking progress), which other less standardized but more economic training methods cannot.[16,18,19]

### Conclusion

In this study performed at Cairo University, cataract surgeons showed significant improvement in test scores of their non-dominant hands with simulator training. We appreciate that this study has limitations; novice surgeons were not included and the number of intermediate surgeons was small in comparison to experienced ones. Future studies should explore whether simulator training of the non-dominant hand directly improves true cataract surgical skills. Being microsurgical procedures, both cataract and vitreoretinal surgeries share some technical skills.[6] Accordingly, further studies can test the benefit of training the non-dominant hand of vitreoretinal surgeons.

Training with simulators has shown large effects on knowledge, skills, and confidence and moderate effects on patient-related outcomes across various surgical and medical fields.[16] Thus, training of the non-dominant hand can be incorporated in surgical simulator training programs for improving skills without jeopardizing the safety of patients.

### Ethics

Ethical approval was waivered (exempted from ethical committee approval) as the study did not include any human or animal participants (solely virtual reality simulator trials).

### Authorship contribution

- Rasha M Eltanamly: Research proposal, data collection and analysis, manuscript writing
- Maha M Youssef: Data collection, data analysis
- Hany E Elmekawy: Data analysis, manuscript editing
- Lameece M Hassan: Research proposal, manuscript writing and editing.

### Financial support and sponsorship

Nil.

### Conflicts of interest

There are no conflicts of interest.

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