ARTICLE

Correlation of virtual reality performance with real-life cataract surgery performance

Mads Forslund Jacobsen, MD, Lars Konge, MD, PhD, Daniella Bach-Holm, MD, PhD, Morten la Cour, Dr Med, FEBO, MPG, Lars Holm, MD, PhD, FEBO, Klavs Højgaard-Olsen, MD, Hadi Kjærbo, MD, George M. Saleh, FRCS, FRCOphth, Ann Sofia Thomsen, MD, PhD

Purpose: To investigate the correlation between performance on a virtual reality simulator and real-life cataract surgical performance.

Setting: Nine ophthalmology departments in Denmark and Copenhagen Academy for Medical Education and Simulation, Copenhagen, Denmark.

Design: Prospective multicenter study.

Methods: Cataract surgeons with different experience levels were included. The participants performed 3 consecutive video-recorded phacoemulsification surgeries that were rated by masked raters using the Objective Structured Assessment of Cataract Surgical Skills (OSACSS) scoring system. Thereafter, the participants performed a previously validated test on an Eyesi virtual reality simulator. Primary outcomes were the mean OSACSS score from all 3 surgeries and the simulator score from the participants' first repetition of the performance test.

Result: Nineteen surgeons participated. There was a statistically significant correlation between the simulator performance score and the mean OSACSS score across all experience levels, with a Pearson correlation of 0.65 ($P = .003$, $R^2 = 0.42$).

Conclusion: Simulator performance was significantly correlated with real-life cataract surgical performance.

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Cataract surgery is one of the most common surgical procedures in the Western world[1]; however, it is a demanding and complex procedure that requires excellent visuospatial skills. Therefore, to achieve the best possible patient outcomes, the surgeon must be competent and qualified through training.

Traditionally, training has been done using a master–apprentice approach of supervised surgery on real-life patients.[2] This method of education is still dominant in many countries[3]; however, the result is a high rate of complications in the beginning of the novice surgeon's learning curve.[4] To avoid this, simulation training on porcine eyes, inanimate eye models, and virtual reality-based surgical simulators are increasingly being used during the first steep part of the learning curve. These methods provide a safe environment for the novice surgeon to achieve competency without having the patients bear the burden of the novice surgeon's learning curve. The question is how much a novice surgeon must train in a simulated environment before progressing to real-life patients. All trainees learn at a different pace, and a predefined number of training hours or repetitions does not ensure competency; the principles of mastery learning must be applied.

In mastery learning, the trainee trains until he or she has reached a predefined skill level. Although experienced surgeons can assess this, evaluation of cataract surgical proficiency by human raters is labor intensive, depends on the individual assessor, and is prone to bias.[5,6] As a consequence, there is a demand for unbiased automated assessment tools independent of social considerations and intuition. Virtual reality (VR)-based surgical simulator metrics offer objective measurements of surgical

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From the Department of Ophthalmology (Jacobsen, Bach-Holm, la Cour, Holm, Højgaard-Olsen, Kjærbo, Thomsen), Rigshospitalet–Glostrup, Copenhagen Academy for Medical Education and Simulation (Jacobsen, Konge, Thomsen), Centre for HR, Capital Region of Denmark, Department of Clinical Medicine (Bach-Holm), Faculty of Health and Medical Sciences, University of Copenhagen, Denmark; the National Institute for Health Research (Saleh), Biomedical Research Centre and UCL Institute of Ophthalmology, Moorfields Eye Hospital, London, United Kingdom.

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Corresponding author: Mads F. Jacobsen, MD, Rigshospitalet, Blegdamsvej 9, 2100 Copenhagen, Denmark. Email: mads.forslund.jacobsen@regionh.dk

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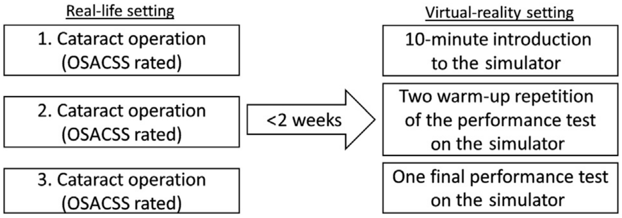

Figure 1. Study design (OSACSS = Objective Structured Assessment of Cataract Surgical Skills).

proficiency because the assessment process does not include a rater.[7] Furthermore, VR simulation offers a more standardized assessment process by providing settings and tasks independent of available clinical cases, which vary in difficulty.

The Eyesi simulator (VRmagic Holding AG) is the most widespread and investigated VR-based simulator in cataract surgery.[8] Despite being widely used in the education of ophthalmic surgeons, to our knowledge no prospective studies have assessed the direct correlation between VR performance and a human-rater system. As a consequence, the direct link between Eyesi simulator performance and real-life performance of a full cataract surgery remains largely undocumented.

In this study, we evaluated the correlation between performance on the Eyesi VR simulator and real-life cataract surgical performance.

PARTICIPANTS AND METHODS

This was a multicenter observational study with masking of the raters and outcome assessors. Additional data from a previously published study[9] was collected, and the relevant background for this study was documented.[9] The Ethics Committee, Capital Region of Denmark, ruled that approval was not required for this study (protocol no. H-6-2014-011). The study adhered to the tenets of the Declaration of Helsinki and was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology for simulation research guidelines.[10]

Participants

Cataract surgeons from Denmark were included in the study. Surgeons were invited from all ophthalmology departments in Denmark, including two private clinics. Cataract surgeons of all experience levels were enrolled, including surgeons not yet operating independently (ie, performing only single steps of cataract surgery). All participants gave oral and written consent before they were included in the study. Thereafter, they completed a questionnaire regarding demographic data and their surgical experience. Further details are given in a previous study.[9]

Data Collection of Real-Life Surgeries

The participants performed 3 consecutive phacoemulsification surgeries immediately before performing the simulation test. Figure 1 shows an overview of the study design. The participants operated only on uncomplicated cataract cases. An uncomplicated cataract case was defined as being performed under local anesthesia and performed on patients older than 60 years with a preoperative corrected distance visual acuity better than 1/60 (measured using a standard Snellen chart at 6 m). To ensure that participants did not select specific operations to be included in the study based on personal preferences, the timing of the surgery was cross-checked. The novices disclosed which surgical steps their supervisor had performed. All phacoemulsification techniques (including divide-and-conquer and phaco-chop) were allowed. The exclusion criteria were more than 2 weeks between surgeries and the performance test on the simulator and an inability to provide video recordings of the performed operations.

After the video recordings were captured, the surgeries were anonymized by removing the identity of the patient and the surgeon. Thereafter, the videos were presented in a random order to 3 masked cataract surgeons through secure web-based video-rating software. The outcome assessors were masked to the identity of the surgeons by removing person-identifiable data and sound from the videos.

The Objective Structured Assessment of Cataract Surgical Skill (OSACSS) rating scale[11] was used to evaluate the technical performance of all cataract surgical recordings of participating surgeons. The OSACSS is a widely used tool that rates performance for all steps of a cataract surgery. In the assessment of cataract surgical skill, the OSACSS is considered by many to be the gold standard. Results in previous research suggest that the OSACSS is a valid assessment tool.[11]

The rating scale consists of task-specific items and global indices. The OSACSS scale was adjusted to include only the items performed by the surgeon. This meant that the first item regarding draping was omitted because in Denmark the surgical assistant regularly performs this step of the procedure. The final assessment of technical performance thus included 13 task-specific items. These items were rated using a 5-point scale that ranged from 1 (inadequately performed) to 5 (well performed). Global indices were rated but were not included in the final score to allow comparison between non-independent surgeons and independently operating surgeons. The final scale ranged from 15 to 65 points, with 65 points representing superior performance. Three independent raters evaluated all videos and were trained before study initiation to reduce rater errors and ensure standardized assessment. For the non-independently operating surgeons, steps performed by the supervising surgeon were adjusted to the lowest possible score (poorly or inadequately performed = 1 point) post hoc by the primary investigator. This was done to avoid giving the novice points for steps performed by the supervising surgeon. The mean technical performance from all 3 real-life surgeries measured by OSACSS score was the first primary outcomes in this study. Figure 2 shows the OSACSS rating scale.

Simulator Assessment

The performance test on the VR simulator was performed at the Simulation Centre at Rigshospitalet, Copenhagen Academy for Medical Education and Simulation. The surgeons included did not perform cataract or other intraocular surgeries during the testing on the simulator. The cataract interface on the simulator (version 2.8.10) was used for the test. A previously established performance test with evidence of validity was used for the assessment.[12]

All participants received a 10-minute introduction to the simulator. Immediately thereafter, participants completed two warm-up repetitions of the test, followed by one final performance test. The length and structure of the introduction and warm-up period were based on previous studies.[7,12] Because of the study design, participants had not trained on the simulator before the assessment and were therefore naïve to its use. The included performance test was the participant's first structured use of the simulator after the introduction and warm-up period. One author (AST) gave instructions to all participants during the performance test and ensured that all participants completed the entire test. The simulator test had a maximum potential score of 700 points (7 modules with a maximum potential score of 100 each), derived from the final performance test, which was recorded. This served as the second of the primary outcome measures in this study. Table 1 shows details of the performance test, including the simulator settings and difficulty level chosen for each task.

Skill	Poorly or Inadequately Performed		Performed with Some Errors or Hesitation		Performed Well with No Prompting or Hesitation	Tick If Not Performed
Incision and paracentesis: formation and technique	1	2	3	4	5	
Viscoelastic: appropriate use and safe insertion	1	2	3	4	5	
Capsulorhexis: commencement of flap	1	2	3	4	5	
Hydrodissection: visible fluid wave and free nuclear rotation	1	2	3	4	5	
Phacoemulsification probe and second instrument: insertion into eye	1	2	3	4	5	
Phacoemulsification probe and second instrument: effective use and stability within the eye	1	2	3	4	5	
Nucleus: sculpting or primary chop	1	2	3	4	5	
Nucleus: rotation and manipulation	1	2	3	4	5	
Nucleus: cracking or chopping with safe phacoemulsification of segments	1	2	3	4	5	
Irrigation and aspiration technique with adequate removal of cortex	1	2	3	4	5	
Lens insertion, rotation, and final position of intraocular lens	1	2	3	4	5	
Wound closure (including suturing, hydration, and checking security as required)	1	2	3	4	5	

Figure 2. Modified Objective Structured Assessment of Cataract Surgical Skill rating scale (Viscoelastic = ophthalmic viscosurgical device).

Statistical Analysis

Statistical analysis was performed using SPSS software (version 22.0, IBM Corp.). Linear regression analysis was used to determine the correlation between the simulator performance score and the mean OSACSS score. The Pearson correlation coefficient was calculated between the test score and the mean OSACSS score. Higher simulator test scores and higher OSACSS scores were considered better.[11,12] A positive Pearson correlation indicated that both variables increased or decreased together.

RESULTS

The entire cohort of 19 enrolled cataract surgeons was included in the final data analysis. One of the operations for each of two surgeons was not video recorded because of technical problems, 1 patient was excluded for being too young, and 1 complicated case (white cataract) was excluded. Instead, the subsequent operation was video recorded and included in all 4 of these cases. The mean time between the cataract operations and the simulator performance test was 5 days. The surgeons were between 37 years and 58 years old (median 40); 13 (68%) were men and 16 (84%) were right handed. Stereoscopic acuity ranged from 15 to 240 seconds of arc (median 30) measured by TNO test. The number of cataract surgeries performed by each surgeon ranged from zero independent surgeries to 24 200. Table 2 shows the performance details for each included surgeon.

There was a statistically significant correlation between total simulator score and the mean OSACSS across all experience levels, with a Pearson correlation of 0.65 ($P = .003$, $R^2 = 0.42$) (Figure 3). The expected change in the mean OSACSS score resulting from a 100-unit change in the simulator score was estimated to be 12.6 (95% confidence interval, 5.1-20.1).

Table 1. Performance test on the virtual reality simulator.

Module	Task Name	Task Description	Test Level	Level	Points
1	Intracapsular navigation	Aiming at objects within the capsule with tip of instrument (abstract task)	3	2	0–100
2	Anti-tremor training	Following circular path on capsule with tip of instrument (abstract task)	7	4	0–100
3	Intracapsular anti-tremor training	Following circular path within capsule with tip of instrument (abstract task)	5	2	0–100
4	Forceps training	Collecting objects in anterior chamber with forceps (abstract task)	4	4	0–100
5	Bimanual training	Aiming at objects simultaneously with 2 instruments (abstract task)	5	5	0–100
6	Capsulorhexis	Performing a continuous curvilinear capsulorhexis (procedural task)	3	1*	0–100
7	Phaco: divide and conquer	Performing phacoemulsification on medium-hard lens (procedural task)	8	5	0–100

*Capsulorhexis: weak zonular fibers; no initial tear

Table 2. Simulator test score and mean OSACSS score for each individual surgeon and the overall mean.

Surgeon	Surgeries Performed (n)	Score	
		OSACSS*	Simulator†
1	0	20	377
2	0	34	538
3	0	26	549
4	0	33	494
5	2	31	611
6	3	31	511
7	30	51	606
8	75	42	485
9	186	53	661
10	200	51	618
11	500	55	547
12	700	60	640
13	700	54	522
14	750	59	518
15	800	60	616
16	900	55	631
17	1,5	58	628
18	12	62	601
19	24	62	609
Mean	—	47 ± 13.7	566 ± 71.0

Means ± SD
OSACSS = Objective Structured Assessment of Cataract Surgical Skills
*Maximum 65 points
†Maximum 700 points

Furthermore, assessment of the correlation between the individual simulator score for each module included in the test and the mean OSACSS score across all experience levels showed that intracapsular anti-tremor training level 2 (module 3) had a statistically significant correlation with the mean OSACSS score, with a Pearson correlation of 0.64 ($P = .003$, $R^2 = 0.407$). Furthermore, capsulorhexis level 1 (module 6) also had a statistically significant correlation with the mean OSACSS score, with a Pearson correlation of 0.47 ($P = .041$, $R^2 = 0.224$).

DISCUSSION

This study found a significant correlation between the Eyesi simulator score and the mean OSACSS score across all experience levels. The results indicate that the combined simulator score is a valuable assessment tool. Previous studies[12–14] have documented that several modules on the Eyesi simulator show evidence of validity and that performance is correlated with surgical experience. In addition, the total Eyesi score is correlated with variables such as surgical experience and intraocular motion tracking in real-life surgery.[7,15] Furthermore, a transfer of skills from the Eyesi simulated setting to the operating room has been shown, indicating a correlation between simulator performance and real-life performance.[9] Finally, one study[16] assessed the link between VR performance and real-life cataract surgical performance using the Global Rating Assessment of Skills in Intraocular Surgery; however, the ability to reach conclusions is limited because of the study's retrospective design.

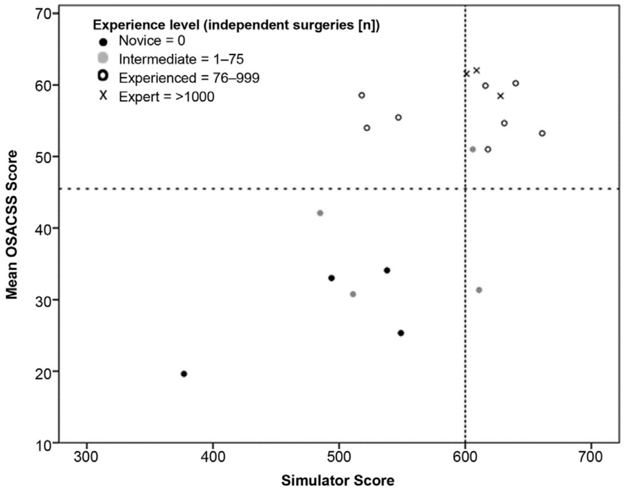

Figure 3. EyeSi simulator score versus mean OSACSS score. The vertical line represents a previous established simulator pass/fail score of 600/700 points.[1] The horizontal line shows a mean OSACSS of 45.5, which represents a superior performance (OSACSS = Objective Structured Assessment of Cataract Surgical Skills).

The findings in our study add further weight to previous reports that the Eyesi simulator is a valuable tool in the assessment of cataract surgical skill. However, as our study results show, the simulator score can only account for part of the interindividual variance in the mean OSACSS score; the exact relationship should evaluated in future studies. Furthermore, the Eyesi simulator is designed to train and assess purely technical skills. However, surgical competency can be defined in many ways and encompasses both technical and nontechnical skills.[17] Therefore, to obtain the best understanding of a trainee's surgical competency and achieve the fairest and most accurate assessment process, educators should rely on the use of multiple assessment tools.[18] At present, the recommendation is that the assessment of surgical competency in ophthalmology should comprise multiple assessments by multiple observers using multiple tools at multiple timepoints.[19] Our study findings support these recommendations.

In this study, we assessed the use of the Eyesi simulator as an assessment tool. In general, an assessment tool can be used in different ways in to evaluate surgical competency. It serves as part of a proficiency-based surgical training program, helping educators identify which surgical trainees are ready to advance to the next step of the training program, for example from a simulated setting to real patients.[9] In addition, if the performance on the assessment tool is significantly correlated with real-life performance, we can to some extent begin to predict real-life performance from performance on the assessment tool. For example, in the future when further evidence has been gathered, this could potentially aid in the selection of ophthalmic surgeons, identifying which surgical trainees have the visuospatial and technical skills to excel as future ophthalmic surgeons. The challenge of selecting surgical trainees based on visuospatial and technical skills rather than solely on amount of time served in a particular post or on previous academic achievements has been studied for multiple surgical specialties.[20,21] At present, there is no consensus on which types of simulation activities are best for the desired competencies, and more work is needed to assess the efficiency and practicality of incorporating these into the selection process.[22]

It is important to differentiate assessment on the Eyesi simulator from the previously established training effect associated with use of this simulator. The participants in this study had not trained on the simulator before the assessment, and as such were naïve to its use. The assessment in this study consisted of the participants' first structured use of the simulator after receiving an introduction and warm-up period. This is important because we know from previous studies[23,24] that previous experience or repeated training on a VR simulator improves performance. Furthermore, training on the Eyesi simulator can lead to a ceiling effect in which the difference between the final performances of trainees will be minimal.[25] As a consequence, the correlation with real-life performance will cease to exist. These factors impose limitations on the application of the Eyesi simulator as an assessment tool. The simulator is, in its current form, best suited to assess the surgical performance of simulator-naïve emerging ophthalmic surgeons and is not suitable for reassessing and recertifying active surgeons with previous training experience on the simulator.

Using VR-based simulators as an assessment tool offers several potential advantages over conventional assessment methods. They provide continuous feedback, and are less labor intensive than their human counterparts.[5–7] In addition, they enable a more standardized assessment environment than found with the inherent variability of surgical cases of varying complexity. An example of the potential source of human bias, even with anonymized video review by the 3 masked raters, is as follows: Despite anonymization of both the patient and the surgeon, assessors are still subjected to the halo effect. In brief, the halo effect, first described by Thorndike in 1920,[26] is a type of cognitive bias in which our overall impression of a person influences the way we think about his or her character. Translated to our study setting, this could mean that if a surgeon performs exceptionally well in the first few minutes of the video-recorded surgery, assessors will tend to look more favorably on the rest of the surgery, despite varying performance. This aspect is eliminated when virtual-reality simulators are used for automated assessment because the machine is not subjected to the laws of human psychology.

Another possible source of bias is the intrinsic effect of seniority on assessment by human raters. Previous studies have shown that when assessment is performed under direct observation, senior staff members tend to score higher than trainees compared with results of a blinded assessment.[6] We chose to use video-based assessment to minimize the bias of human relationships between the rater and the surgeon being rated.

When using the Eyesi simulator as an assessment tool, the warm-up effect associated with use of the simulator must be addressed. It has been shown that familiarity with the technical features of the simulator can influence performance, even for experienced surgeons.[12,27] This might influence the initial performance score on the simulator. Introducing a warm-up period before the simulation-based assessment can minimize this effect. This warm-up period must be of appropriate length and not too extensive or it will influence performance on the simulator by affecting the participant's learning curve. These effects were factored into our study design, and all participants completed a 10-minute introduction followed by two warm-up repetitions of the performance test, based on previous studies.[7,12]

Training using the evidence-based performance test on the Eyesi simulator can improve performance in the operating room for novice and intermediate cataract surgeons.[9] To avoid this training effect and prevent influencing the participants' cataract surgical performance, the real-life cataract surgeries were performed and video recorded before the virtual-reality performance test. We believe this gave the most accurate representation of the participants' real-life cataract surgical performance.

Our study assessed the correlation between VR performance and real-life cataract surgical performance measured by a human rater system. We found that the Eyesi simulator performance was significantly correlated with real-life cataract surgical performance measured using the OSACSS. This suggests that the increased use of VR simulators in the assessment of surgical competency might be warranted.[8] Moreover, it indicates that the Eyesi simulator could be a valuable tool for assessing cataract surgical competency. In the future, the Eyesi simulator score might take its place among other assessment tools and aid educators in the evaluation of emerging ophthalmic surgeons.

WHAT WAS KNOWN

- The virtual reality simulator is widely used in the training of emerging ophthalmic surgeons.

WHAT THIS PAPER ADDS

- The study's findings support the growing evidence that the virtual reality simulator might be a useful tool in the assessment of cataract surgical skill.

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First author:
Mads Forslund Jacobsen, MD

Department of Ophthalmology, Rigshospitalet–Glostrup, Copenhagen, Denmark