

Review article

Cataract surgery training using surgical simulators and wet-labs Course description and literature review



Saeed Alwadani*

Abstract

Cataract surgery is the most common surgery to face the ophthalmology training resident. To facilitate achieving surgical competency and reduce complication rates, wet laboratories and surgical simulators are used in surgical disciplines worldwide. We developed a simulator and wet-lab course that aims to build the microsurgery skills of trainees and improve safety during real surgical procedures. Herewith, we describe the standardized hands-on course that incorporates these tools for advanced training. Additionally, we review the literature on wet-lab and surgical simulators in ophthalmology, focusing on their importance in training centers. The course is offered four times per year since it started in December 2015, and a total of 88 trainees participated to date. Feedback received from the trainees' supervising surgeons showed that this course addresses a major training challenge, and that a permanent version of this course should be established at each training center. We suggest incorporating fixed wet-lab and surgical simulator competencies in ophthalmology training programs. Additionally, we recommend that residents be allowed to operate on real patients only after passing the course. We believe that these steps would foster ophthalmologists with advanced training, decrease their learning curve, and empower them to safely conduct cataract surgery with low complication rates.

Keywords: Cataract, Wet-lab, Simulator, Training

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Introduction

Almost half of all cases of blindness worldwide are attributed to cataract.¹ Consequently, cataract surgery is the most common ophthalmic surgery.² However, ocular surgery in general, and cataract surgery in specific, requires extreme precision, meticulousness, as well as advanced hand-eye coordination and fine motor skills. Training is also resource-intensive and time-consuming.³ Nevertheless, these vital skills must be acquired and refined during residency training years, and by the time a trainee is board-certified in ophthalmology, they are expected to have developed a mature skill-set that allows them to safely conduct cataract surgery.

While classic apprenticeship-style training models allow for effective knowledge transfer, surgical skill acquisition requires extensive, supervised hands-on training and practice.³ Moreover, the delicate nature of the ocular tissue and the small scale of the eye's anatomical components result in a low tolerance for error.⁴ However, microsurgery often employs a single surgeon thus leaving little to no room for an assistant. These factors result in insufficient hands-on experience, which was found to translate to a significantly higher complication rate comparing inexperienced with experienced ophthalmology surgeons.⁵ Therefore, alternative teaching methods are sought to bridge between theory and practice.

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Department of Ophthalmology, College of Medicine, King Saud University, Riyadh, Saudi Arabia

* Address: Department of Ophthalmology, College of Medicine, King Saud University, 2714 Ali Ibn Abi Tahir, Al Wahah, Riyadh 12444, Saudi Arabia.
e-mail address: saeed5400@hotmail.com



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Training in ophthalmology surgery has moved away from pure apprenticeship towards wet laboratories and surgical simulation.^{6,7} These methods deliver interactive platforms that demonstrate complex anatomical relationships and provide a hands-on three-dimensional experience that is otherwise unattainable. This allows residents to practice basic microsurgery techniques, and acquire vital skills needed to safely perform ocular surgery. Multiple studies have reported that simulator and wet-laboratory training improve the surgical performance in ophthalmology, shortens the learning curve of the residents and surgical time and decreases the surgical morbidity and the risk of iatrogenic trauma.^{8–11}

Ophthalmology residency training started in 1984 in Saudi Arabia. Nowadays, there are 7 ophthalmology training center programs in the country under the Saudi Commission for Health Specialties (SCFHS).¹² To contribute to the advancement of ophthalmology training programs in the Kingdom and support residents-in-training, we developed a proficiency-based virtual reality and a wet-lab course that aims to build the microsurgery skills of trainees and thereby improve safety during real surgical procedures. In this paper, we review this course, the evidence base behind it, and provide a framework for establishing a fixed, permanent version of this course in ophthalmology training programs across the country.

Course materials and methods

The course is organized by the Department of Ophthalmology, College of Medicine, King Saud University in collab-

oration with the SCFHS and the Saudi Ophthalmological Society. The supervisors are academic faculty from King Saud University and expert cataract surgeons from other centers. In accepting candidates, priority is given to 2nd-year residency trainees. The 5-day hands-on course described in this paper was first employed in December 2015. The course is currently offered four times per year.

The main general learning objectives of the course are:

- To reduce errors during real surgical procedures and allow trainees to safely and confidently perform cataract surgery performance,
- To improve fine motor skills under an operating microscope,
- To gain experience in all steps of phacoemulsification and extracapsular cataract extraction (ECCE) surgery using iris hooks retraction, and single and three pieces IOLs,
- To perform continuous curvilinear capsulorhexis of appropriate size,
- To identify the different instruments and their uses in cataract surgery,
- Learn about IOL designs, and
- To understand the general principles of phacoemulsification machines and dynamics (Table 1).

Course station distribution

The course encompasses five stations. Each one has up to two residents who spend two hours at each station under an

Table 1. Specific learning objectives of the course.

<i>ECCE skills</i>
Perform superior rectus bridle suture
Perform conjunctival peritomy using electrocautery
Perform the three-steps of sclero-corneal wound creation
Enter AC by Super Sharp Blade
Stain anterior capsule with Vision Blue and wash with BSS irrigation solution, followed by OVD to maintain AC
Manipulate cystetome using needle-holder to perform can-opener capsulotomy technique
Extend corneoscleral wound and lens delivery
Remove cortex using irrigation-aspiration
Implantation of PMMA IOL into capsular bag under viscoelastic device
Aspirate viscoelastic device after suturing the sclerocorneal wound
Use different types of ophthalmic sutures and needles
Understand principles of suture placement and needle passage
<i>Phacoemulsification skills</i>
Train on proper placement and length of corneal incisions
Demonstrate paracentesis with a 3-step entry and proper placement of corneal incision that is neither too long causing corneal striae nor too short causing iris prolapse
Create an appropriate scleral tunnel incision of adequate length and its three steps entrance procedure
Ensure that scleral tunnel length does not cause decreased visibility through the cornea, neither entering into anterior chamber nor posterior, causing iris prolapse
Understand different categories of OVDs, their properties, preferred use
Inject viscoelastic into the eye before IOL implantation or before capsulorhexis
Use irrigation and aspiration to remove OVD and cortical material
Create an adequately-sized capsulorhexis with easy insertion of IOL and good fixation
Understand principles of the technique and the difference between hydrodissection and hydrodelineation
Ability to do hydro-dissection, hydro-delineation using BSS
Complete "groove" of appropriate depth, length, and width with minimal stress on zonules
Crack nucleus and rotate nucleus with minimal stress on zonules.
Remove quadrants, taking care to keep quadrant in iris plane (away from capsule and endothelium)
Remove epinucleus and cortex
Choose the appropriate lens
Learn about different IOL formulas and biometry
Load and insert a 1-piece PCIOL into the capsular bag
Load and insert a 3-piece PCIOL into the sulcus
Insert a folded 3-piece PCIOL into the sulcus, using folding forceps

experienced supervisor. The first station has two phacoemulsification machines and two ophthalmic microscopes with full ophthalmic theater instruments (Fig. 1). The second station has corneal suturing with ECCE equipment including a microscope and suturing and ophthalmic instruments. Both goat and artificial eyes are used for training in these two stations (Fig. 2). The third station has videos of theoretical information about cataract surgery steps, instruments, and demonstrations on the management of intraoperative complications (Fig. 3). The fourth station has an Eyesi Ophthalmic Surgical Simulator (VRMagic, Mannheim, Germany; Fig. 4), and the last station is located in the ultrasonography department for hands-on practice on real patients.



Fig. 1. Participant training in the phacoemulsification station while being guided by course faculty (SA).



Fig. 3. Theoretical Video Station showing cataract surgery and management of perioperative complications.



Fig. 4. Course participant training on the EYESI Simulator (VRMagic, Mannheim, Germany).

A total of 88 trainees enrolled in the course since it was first provided in December 2015, of whom 71 (80.7%) were residents in training (Fig. 5). Almost half ($n = 41$, 46.6%) of all participants were from the central region, followed by Assir region ($n = 11$, 12.5%; Table 2).



Fig. 2. (A) Goat eyes placed on mannequin head; (B) artificial cataract eyes used in the course.

Distribution of Course Participants

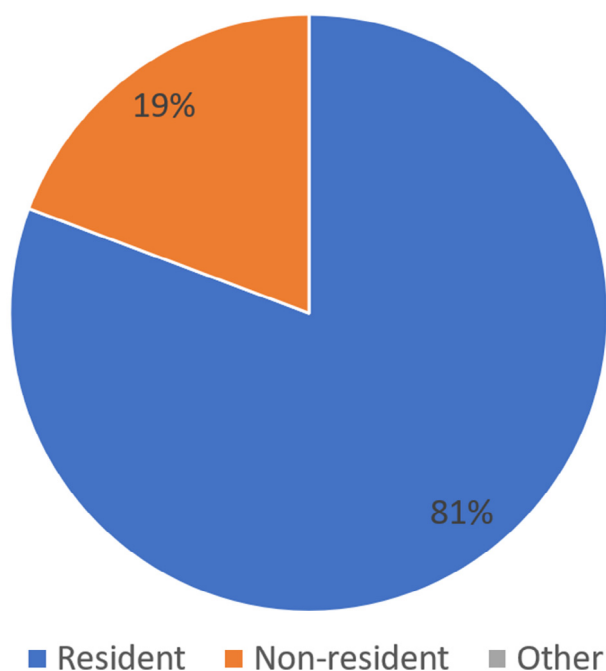


Fig. 5. Distribution of course participants according to training status to date.

Table 2. Distribution of course participants according to geographical region.

Area	Number of trainees, n (%)
Riyadh Training Center	41 (46.6)
Assir Training Center	11 (12.5)
Western Region Training Center	9 (10.2)
International ^a	2 (2.3)
Eastern Region Training Center	6 (6.8)
Medina Training Center	2 (2.3)
Other/Non-training	17 (19.3)

Training Center: Training center operating under the Saudi Commission for Health Specialties.

^a Participant from center outside Saudi Arabia (One from France, one from Bahrain).

Discussion

The use of wet-labs and simulation for training in ophthalmology has had rising evidence of improvement in the outcome of the trainees.⁷ To the best of our knowledge, this is the first report on a virtual reality and wet-lab ophthalmology training course for cataract surgery in KSA. Residents and expert ocular surgeons in KSA have previously recognized the imperative need to develop such programs for ophthalmic surgery skill acquisition.¹³ Feedback received from the trainees' supervising surgeons showed that this course addresses a major training challenge, and that a permanent version of this course should be established at each training center. Many simulations and wet-lab training programs have been developed worldwide in recognition of the difficulties faced in acquiring the skills necessary to perform cataract surgery. Several studies have confirmed that such programs lead to a significant reduction in the surgical complication rate.^{14,15} After introducing an intensive capsulorrhexis course

that utilizes the Eyesi virtual simulator for ophthalmology residents, McCannel and colleagues observed a significant, 3-fold reduction in the rate of errant continuous curvilinear capsulorrhexis.¹⁴ The University of Iowa implemented a comprehensive cataract surgery curriculum that includes structured and supervised wet-laboratory training sessions. The faculty of the University of Iowa observed a significant decrease in vitreous loss and posterior capsular tear even after adjustment for surgical experience.¹⁵

Studies from centers that lack a skills acquisition program similar to the one described in this paper show a deficiency in the abilities of ophthalmology trainees to meet local certifying board requirements.⁴ Before the implementation of mandatory training wet labs in the United Kingdom, just over 40% of the trainees with two or more years of training met the Royal College of Ophthalmologists requirement of 50 completed intraocular operations.¹⁶

Although some might question the ability of wet labs to mimic the conditions of a real-life situation, an overwhelming set of published work finds the opposite to be true.^{17,18} The University of British Columbia has previously reported on their experience with the Basic Surgical Techniques program; they found that undergoing simulated training in animal models leads to a significant improvement of surgical skills.¹⁸ Kirby reported on the use of basic surgical technique courses as a means of training in ophthalmology surgery in 1966, the first reported early version of a wet lab.¹⁹ Although there is sufficient evidence over the importance of hands-on courses in ocular surgery, not all training programs in Saudi Arabia have a permanent version of such a course. It is this aspect that we argue in this paper would yield well-prepared ophthalmology surgeons after the completion of their training program.

From our experience with this course, we found that goats' eyes were excellent for ECCE surgery skill acquisition, as well as training on steps before capsulorrhexis and soft cataract phacoemulsification. Other steps like iris hooks retraction and insertion of three piece IOLs in the sulcus space feel the same in human and goat eyes. Regarding artificial eyes and the Simulator, we felt that performing capsulorrhexis and phacoemulsification steps was close to reality. For this reason, we preferred to include goat eyes, artificial eyes as well as the virtual simulator in this course to allow the trainee to practice in an environment that is as similar to reality as possible. Lastly, we also provided training using a Kitaro Kit (FCI Ophthalmics, Pembroke, MA, USA). This kit replicates phacoemulsification steps, especially capsulorrhexis and cracking of the nucleus, without requiring the availability of an actual phacoemulsification machine (Fig. 6).

Kloek et al. had suggested the inclusion of a cataract surgery within the residency program, particularly by training on the individual steps of the surgery under a structured curriculum.²⁰ This suggestion is also justified by our findings, as the program we developed emphasizes on this step-wise approach with clear objectives to teaching cataract surgery to trainees. Interestingly, several studies have found, similarly, the importance of the inclusion of such training in the residency program, with reports of the need for a standardized training program that includes a wet-laboratory.²¹ Lee et al. designed a wet laboratory curriculum for their institution to not only teach residents the necessary skills they need but also to provide a framework for effective evaluation.²²

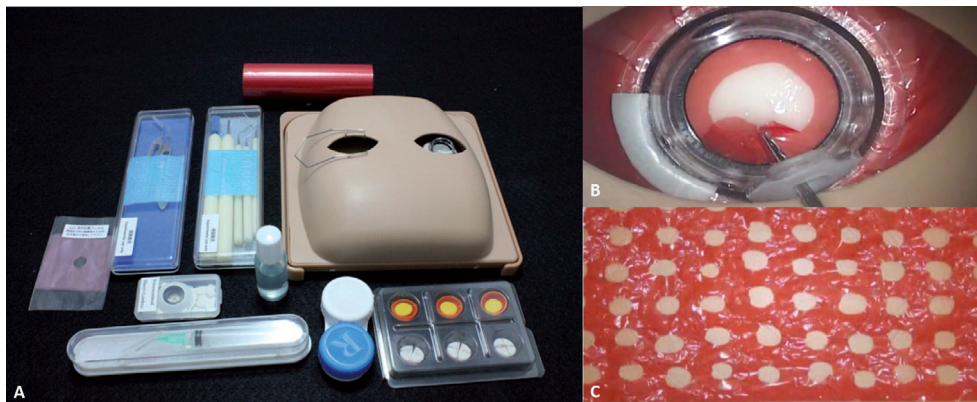


Fig. 6. (A) Kitaro Kit with material used for phacoemulsification training; (B) Photograph showing Continuous Curvilinear Capsulorrhexis (CCC) on Kitaro Kit; (C) Photograph showing numerous repeated CCC attempts using the Kitaro Kit.

Emphasis on the need for a fixed version of this training course cannot be overstated.

The techniques in the wet-lab used to train surgeons can vary, and the use of virtual reality has been proven to improve the performance of ophthalmology surgeries by increasing the skills of the novice trainees and shortening their learning curve.^{8,10}

The importance of virtual reality lays in an often criticized area of wet labs and that it is unrealistic, inaccurately simulating tissue anatomy and consistency with no room for objective assessment.^{17,23} This can be resolved with the development of computer simulators that provide a real-life situation using the virtual reality technique, as many existing programs incorporate the technology slowly developing.^{24,25} The importance of these techniques is in their transferability to the operating room, and the tools developed need to be ruinously evaluated.²⁶ Indeed, studies have shown the significant increase in the performance of novice trainees in ophthalmology programs using virtual reality wet labs with significant levels of skills transfer, recommending it at an early stage of the program.^{7,27} Training with a simulator showed improvement in phacoemulsification times with fewer intra-operative complications and a shorter learning curve for the trainees.⁹ Using simulators for training Solverson et al. found that novices had significant and continued improvement on their dexterity.¹¹ Similarly, Pokroy et al. reported a shorter learning curve for trainees using simulators and highlighted that novices are those that benefited the most.¹⁰

The course we described in this paper is not purely directed residents in-training. Licensed surgeons can leverage on this course to refine their techniques and to test new ideas. Additionally, practice and training on the use of novel instruments, consumables and other material can be safely performed through this course.²⁸

We set out to document our approach to wet-lab practice in ophthalmology training programs in an attempt to propose an applicable standard to the community with an applicable standard. Essentially, we aim to provide a replicable step-by-step guide to all ophthalmology training programs within the Kingdom to incorporate within their curriculum with all the necessary set-up and equipment needed. We also aim to set a basis for future studies on the level of efficacy and quantify the learning curves in this program to further refine it to meet the needs of the field.

This report provides a framework for training centers to establish local, permanent wet-lab and surgical simulator skills centers. Future studies will evaluate the impact of establishing this center on cataract surgery performance.

Conclusion

The use of wet-labs and simulation in training is essential to the development of vital skills needed in safely performing ophthalmic surgery, and improve cataract surgery performance. It provides an improved level of skills transfer from surgeons to trainees. We suggest the development of fixed wet-lab and surgical simulator facilities in training centers to integrate this course during residency training rotations. Additionally, we recommend that residents be allowed to operate on real patients only after passing the course.

Conflict of interest

The authors declared that there is no conflict of interest.

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