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REVIEW ARTICLE

Simulation training in ophthalmology

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Abstract

Background: *Simulation in medicine is an indispensable tool to improve doctors' responses to different situations, enhancing their performance. However, simulation in ophthalmology is a very recent trend, mainly because of the high complexity of developing newer teaching tools, with the need for highly realistic models, mostly in surgical ophthalmic simulation.* **Discussion:** *The whole development of simulation in ophthalmology, from the very first attempts that used basic models, to the newer virtual reality models, allows for a comprehensive, faster, and more efficient development of skills necessary in basic and advance procedures in ophthalmology, creating a better learning environment, improving costs, and developing a very promising panorama, in which simulation can be incorporated in teaching programs all around the globe.* **Conclusions:** *Simulation in ophthalmology allows for better results in the formation of ophthalmologists, and it is becoming a new tool to achieve better results in medical and surgical procedures, thus improving outcomes and quality of care.* (Gac Med Mex. 2017;153:102-6)

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The complexity of ophthalmologic surgery makes for its teaching to be difficult. Simulation is the training that offers the chance for skills constant practice, while the trainee gets familiarized with instruments and equipment. Simultaneously, experience is acquired in problem recognition and decision making, as well as in the refinement techniques and procedures[1]. The difference of medical training with regard to training in other areas lies in that, usually, the physician must learn under situations of stress, instead of controlled simulation situations. In general, simulation in ophthalmology has been focused on surgical technique training, and little emphasis has been put on clinical examination skills, doctor-patient communication and professionalism.

Although simulation applied to medicine has been developing and improving over decades[2], ophthalmology is an area where the incorporation of training simulators and training on different procedures and surgeries started only recently. Most part of studies available in the literature are relatively recent, and information available in Spanish language is scarce.

The purpose of this manuscript is to address the subject of simulation in ophthalmology by reviewing available studies, analyzing their benefits and rationales, as well as its incorporation in the training of ophthalmology residents.

Traditionally, as in many other branches of medicine, simulation in ophthalmology is focused on interactive

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scenarios or by means of the use of laboratories with live animal specimens or cadaveric eyes. Basically, these learning centers or "wetlabs" are found in separate rooms of the ORs and require personnel highly trained on procedures for their teaching. The cost of these surgical teaching laboratories is high, since they must have at least one high-definition surgical microscope, a work table and instruments exclusively dedicated for teaching available. However, their major limitation is not on infrastructure cost, but on the need to have a supervisor (expert surgeon) highly qualified for the procedures. This is why most training programs in Mexico, Latin America and the world have limited wetlabs' adoption.

For a virtual reality simulator to be able to meet the necessary requirements for its adoption in ophthalmology it has to have very high definition[3]. Advances in computing science allow for commercially available simulators to accurately recreate tissue characteristics and to simulate the surgical procedure steps almost entirely.

The use of models and simulators has been reported in different areas of ophthalmology. Ocular fundus examination by means of direct and indirect ophthalmoscopy is one of the skills that can be learned and practiced using these models, which have been used by medical students, general practitioners or specialists in other areas, such as emergency medicine, and ophthalmology residents[4,5]; they have even been used in the training of family medicine residents in the detection of diabetic retinopathy[6]. These models have shown changes over time, since the ones that were initially used were made of plastic and had a photographic slide inserted at the back of each one of the model's eye, and direct ophthalmoscopy was practiced, while current models have high resolution screens and integrated viewers, where a virtual image is shown (Fig. 1). Models for the practice of minor procedures, such as Nd-YAG laser capsulotomy for posterior capsule opacification[7] or for laser application on retinal predisposing lesions[8], have also been created.

Figure 1. *Indirect ophthalmoscopy simulator for the training of ocular fundus examination.*

High-fidelity simulation allows the possibility for most common and important surgical procedures for the practice of ophthalmology to be recreated. Cataract surgery, owing to the complexity of the instruments and the necessity to learn to simultaneously use the four limbs under a magnification environment, has a slow and highly variable learning curve.

To be used in ophthalmology, simulators first have to be validated by documenting, for example, the capacity of the simulator to distinguish between the performance of an expert surgeon and the performance of a novice surgeon on training[9,10]. Ophthalmologists with higher experience on microsurgery techniques have also been shown to display more initial facility at all skill tests[11], and to obtain higher scores in different teaching modules, such as the performance of the crystalline anterior capsule incision (capsulorhexis)[12]. This platform enables novice surgeons to have constant training for the acquisition of specific skills. There are several authors, such as Mahr and Hodge[13] and Selvander and Asman[14], who have assessed and validated the training modules at different phases of cataract surgery (capsulorhexis and crystalline fragmentation), as well as ocular microsurgery essential skills (navigation and use of instruments in the eye anterior chamber and posterior segment).

These simulators also allow for the surgeon performance to be assessed on special situations, including distraction[15], exhaustion[16] or use of the non-dominant hand[17]. Assessing the effect of these real situation components in real clinical scenarios results in an ethical dilemma and risk for the patient; therefore, simulation and the results these studies yield allow for the environment surgeon and patient are in to be modified, with the purpose to improve the surgeon's performance and the quality of care the patient receives.

Currently, there are 3 cataract surgery simulators that have been assessed: Eyesi (VRmagic), PhacoVision (Melerit Medical) and MicrovisTouch (ImmersiveTouch); however, most studies are focused on the first one of them. Eyesi, originally developed for retina and vitreous surgery, is the most widely studied device. The advantages of a virtual reality simulator over

Figure 2. *Cataract surgery simulator.*

a wetlab are clear: it is cleaner and does not require much maintenance and, in addition, allows for exercises to be practiced to be quickly prepared and does not require an infrastructure to handle animal or human tissues. Students are positioned the same way they would in an OR, with a similar microscope and similar instruments and pedals to those used in practice (Fig. 2). For a surgeon who is initiating, positioning him/herself adequately, handling specialized instruments and maneuvering in a reduced surgical field can be a big challenge. The models include an ocular model visible through the microscope lenses, with cornea, iris, crystalline and capsule, and in the specific case of Eyesi, the retina. The produced image is tridimensional and simulates the depth of structures within the eye. The software allows for the equipment to assess the instruments' relative position and provides immediate feedback to the user in order to notice potential damage to structures such as the cornea and crystalline capsule. In addition, the simulation equipment assigns a numeric value to specific tasks (capsulorhexis and fragmentation) that serve to assess the progress and performance of the student. A student can repeat a capsulorhexis procedure, for example, in a wetlab, a limited number of times due to the available number of eyes (usually not more than 3), whereas in a simulation session, repetition can be made as many times as required, which, additionally, is highly comparable with the real procedure (Fig. 3).

Medical simulation in ophthalmology training

The learning of ocular microsurgery skills has a special chapter in medicine. During the training for general physician, the student is exposed to and receives training on general surgery and suture principles to a greater o lesser extent. Ophthalmic microsurgery requires the simultaneous use of the four limbs and movements in a magnified surgical field. The learning curve, usually slow, is an indispensable transition in the acquisition of knowledge and skills. Therefore, surgical time and complications are expected (not only in ophthalmology) to be greater on the first cases, and continuous supervision is therefore required[18,19]. The use of simulators in ophthalmology has great advantages for doctors and patients, since they reduce the lack of

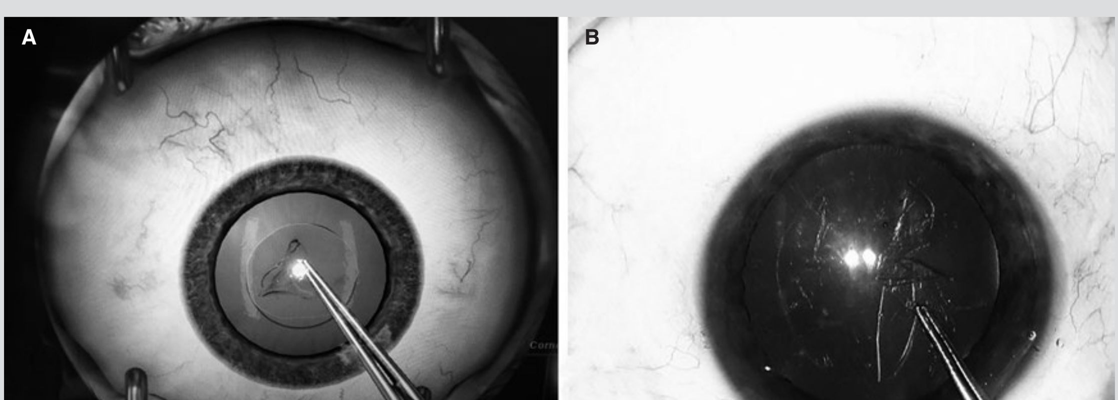

Figure 3. A: *Capsulorhexis procedure in a virtual simulator.* **B:** *Capsulorhexis procedure in real surgery.*

training or little experience prior to exposure to real situations and, hence, they improve the outcomes[20].

Simulation technology-improved healthcare professionals' training, in comparison with training where no such intervention is made, was shown in a meta-analysis to generate important effects on results related to knowledge, skills and behaviors, as well as in patient-related outcomes[21]. For this reason, as in the rest of medicine branches, surgical simulation in ophthalmology has been gradually introduced in residency programs[22], in an effort to increase training without exposing patient health. This is why, at the same time, the need arises to systematically and objectively assess the acquired skills, and today there are multiple assessment tools[23].

With the purpose to generate overwhelming evidence and demonstrate that simulation should be an integral part of training in ophthalmology, a global collaboration program was created, the International Forum of Ophthalmic Simulation (IFOS), which has proposed a structured, sequential and supervised program, and states it can offer significant skills transference, especially at the earliest stages of surgical training in ophthalmology[24].

However, owing to the great diversity in training programs, the moment in ophthalmology programs training when simulation should be resorted to is not yet entirely defined, especially in the case of virtual reality-related simulation. In fact, virtual reality simulation studies and advantages should be extended to classic training methods. One study even suggests that teaching a group of residents in the laboratory with animal specimens did not show differences in any of the assessed variables for capsulorhexis performance in cataract surgery when compared with a simulator-trained group, although it concludes stating that the ideal is the combination of both trainings in an ophthalmology academic program[25].

Owing to its good visual results, immediate rehabilitation and little complications, cataract surgery by means of phacoemulsification is the technique of choice. Its success depends largely on time, on the magnitude of ultrasonic energy and on fluid exchange, which are directly related to surgery duration. Several authors have demonstrated that residents who were trained using virtual reality simulator had shorter surgical times, less energy used, less intraoperative complications and, therefore, a less steep learning curve[26], which suggests that the incorporation of a formal program of simulation-based training may reduce unnecessary risk for complications in real patients[27].

The advantages of including simulation-based training in a residency program include accelerated learning, benefits for training programs and trainers and, most importantly, better patient outcomes. Feedback is one of the most important characteristics of simulation-based medical education, since in addition to the capability of simulators to inform on immediate performance, educators' support allows for the desired learning objectives to be adapted[28]. Simulators provide objective evidence on performance by incorporating follow-up functions and improving performance evaluation, in addition to being able to measure reproducibility and repeatability[29].

Furthermore, there is a wide range in the reduction of costs related to OR time use between residency programs, which entails greater benefit for those larger programs with higher number of residents[30].

Surgery requires physical and cognitive skills coordination to successfully carry out complex procedures. In spite of reading the procedure, assisting in surgery and watching instruction videos, students generally have not formed a complete mental map of each procedure that includes all the components of a surgery and the small steps and details that are required. Their understanding is usually fragile, and the decision making process and the mood change when a step is not carried out just as imagined. Virtual reality-based simulation allows for costs and complications of failure to be eliminated, while offering the chance to learn in such a way that the resident develops more sophisticated and flexible skills and knowledge. Simulation can be used to isolate the surgical skills cognitive process from the physical process and, therefore, reduce emotional and cognitive load. Simulated patients can be especially designed for the student to focus on areas of the procedure where more mistakes are commonly made, without the need to make them, and receive feedback with expert comments on the best way to solve them.

Conclusion

Simulation in ophthalmology is a novel process that has been shown to be effective and that promises to be part of the future of ophthalmologists training programs in the entire world. It should always walk hand in hand with patient personalized care, which is irreplaceable. It is a cost-effective tool for the training of specialized physicians that looks for, as everything in a physician's training, the greatest possible benefit for the patient.

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