

Essentials of setting up a wet lab for ophthalmic surgical training in COVID-19 pandemic

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Wet labs are an extremely important training tool, especially in times of a global COVID-19 pandemic, where surgical training can be minimal. They help the trainee learn and practice in a risk-free environment, without an imminent of a complication or failure, also allowing them the chance to execute the steps of a surgery repeatedly. We summarize all the key ingredients required from setting up a wet lab to improve the surgical skill of the trainees. The review also discusses various eyeball fixating devices, preparation of the eye for various types of ocular surgeries, and the role of simulation-based training in today's scenario.

Key words: COVID-19 pandemic, ophthalmic surgical training, wet lab

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A trainee upon completion of his/her post-graduation is assumed to be confident and competent in operating the common ophthalmic procedures like cataract, trabeculectomy etc. However, the multipolarity in the level of ophthalmic training across the country does not always allow that. On one side, we have newly passed post-graduates who are surgically able to handle these expected surgeries and on another side, we have ones who have not even done a single cataract surgery or extra-ocular procedure. Additionally, just the mere number of surgeries done is not a true indicator for a surgeon's skill level as some may learn earlier than the other. The recent shut down of camp or free surgeries due to the ongoing COVID-19 pandemic has further reduced their surgical training. Moreover, there is an increasing concern of ethics in using patients for training purposes, where there is an inverse relationship between experience and complication rates. These issues highlight the need to establish high-quality wet lab training at various training centers across the country.

A wet lab would help provide a safe and standardized method for training without the risks that come while operating on real eyes. As such, the trainee will be better equipped when he/she does operate on a real eye. Furthermore, this will allow the trainee to do the same surgery multiple times without the tension of a complication or failure. This will instill confidence in the trainee surgeon. This will also help to enhance psychomotor skills, hand eye co-ordination, ambi-dextrousity,

which is very important in ophthalmology. It will also allow trainees to ask sorts of "what if" questions they were previously too afraid to ask or that would cause embarrassment in front of patients or colleagues. Hence, this will allow a less stressful environment to the trainees. This will also permit them to learn immediately from their mistakes. In a nut shell, this will not only prime the trainee but also give a safe working environment to practice without the threat of a devastating complication.

Various improvements in wet lab training have occurred over the years. The purpose of this systematic review is to comprehensively describe all the options available and also give guidelines on establishing a wet lab.

Methods

A systematic search of PubMed was done for articles related to wet lab training, cataract surgery training and ophthalmology training using the key words– wet lab ophthalmology, virtual simulator wet lab ophthalmology, virtual simulator training ophthalmology, goat eye training, (pig OR porcine) AND (eye training) AND (ophthalmology), ((phacoemulsification) OR (cataract surgery)) AND (wet lab training), trabeculectomy wet lab, strabismus wet lab, keratoplasty wet lab, Surgical skills transfer courses (SSTC). Search date was from inception to 16 August 2020. Peer-reviewed articles seen on the search were 320.

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Ten components were identified as important factors for setting up a wet lab. These included- the actual room, designated teaching curriculum, building hand eye coordination, eye ball fixating devices, procuring the eye, eye preparation, virtual simulators, computer & surgical video viewing station, responsibility & ownership and financial backing.

Setting Up of a Wet Lab

A wet lab is the building block of a surgeon’s skills. It is an indispensable component in the armamentarium of a teaching hospital. It helps a trainee to not only attain skills, develop coordination, but also the chance to practice at their own pace in a risk-free environment. It can be the bridge by which a trainee can arrive better prepared to live patient.

Actual location of the wet lab

The wet lab should be ideally located in the main hospital building or somewhere the residents can have easy access to. It should have the space to accommodate at least 2 people (Trainer and Trainee) [Fig. 1]. Ideal room size should be of 10 × 10 feet so that it can easily accommodate microscope, phacoemulsification machine and other things. Table 1 lists all the requirements.

Designed training curriculum

The wet lab allows a risk free environment for a trainee to learn and then sharpen his/her skills. However, the productivity of learning depends more initially on the trainer, as a resident is often confused on how to start and what to expect. One on one session need to be taken by the faculty for each of the trainees in the program on rotation, for which a curriculum designed customized for each institute/centre needs to be incorporated.

A sample wet lab curriculum modified from recommendations of Henderson *et al.*, Oetting *et al.* and Lee *et al.* has been mentioned in Table 2.^[1-3]

Building hand-eye coordination

Ocular surgeries are mostly done under the microscope and it is commonly difficult to do so without practice. Suturing is a vital ingredient of ocular surgeries and should be encouraged to the residents. They could start suturing

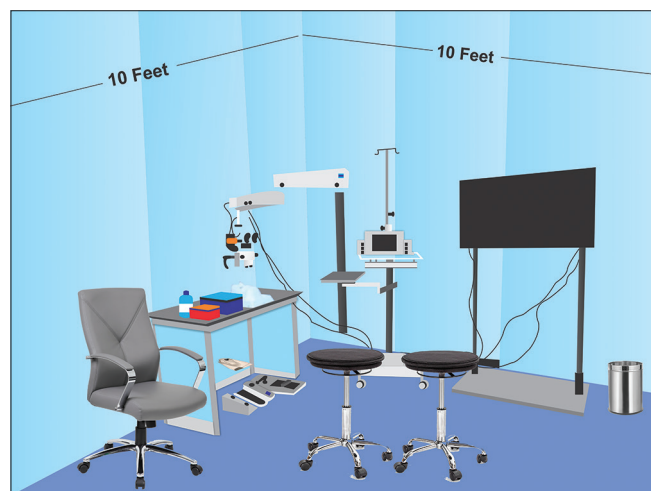


Figure 1: Actual Wet Lab Room having the space to accommodate at least 2 people, trainer and trainee

on a thermacol [Fig. 2a], banana [Fig. 2b], apple or even an orange. This will help the trainee to develop good hand eye co-ordination and also teaches dexterity under the microscope.

Table 1: Requirements for setting up of a wet lab

Minimum Requirements in Actual Room of Wet Lab

- Space to accommodate at least 2 people - Trainer & Trainee
- Table & Sitting Arrangements (adjustable chair preferred)
- Sink with Tap
- Microscope with a side scope or camera connected to a TV screen
- Phacoemulsification machine with Tubings & Expendables
- Surgical Instruments
(A complete surgical set including Suture tying forceps – curved and straight, Mc pherson’s forceps, Lims forceps, Needle holders, Simcoe Irrigation Aspiration Canula Direct, Vannas scissors, Universal corneal scissors, Bard Parker Handle, Superior Rectus forceps, Lens Loop, Sinsky’s hook, Choppers, Hydrodissection cannula, Lens hook, Strabismus Hook)
- Sutures (10-0 Nylon, 8-0 Nylon, 8-0 Vicryl)
- Gloves
- Blades (#15 blade, crescent knife, lancetip knife, keratome 2.8 mm)
- Dustbins with colour coded garbage bags according Biomedical waste guidelines
- Refrigerator/Thermacol Ice Box
- Microwave or OTG (Oven Toaster Grill)
- White Board for teaching
- Storage Almira
- Air conditioner (Preferable)

Table 2: Sample wet lab curriculum (Modified from Henderson *et al.*,^[1] Oetting *et al.*^[2] and Lee *et al.*^[3])

Year of Training	Expectations in Wet Lab
Year 1	<ul style="list-style-type: none"> Knowledge of all instruments in a cataract surgical tray and ophthalmic visco-surgical devices (OVD) Able to put 10-0 Nylon sutures in theramacol, animal/cadaveric eyes Practice making sclerocorneal tunnel in animal/cadaveric eyes Use of Simcoe Canula to aspirate OVDs after injection in animal eyes Place a rigid PMMA IOL in animal eye
Year 2	<ul style="list-style-type: none"> Use cadaveric/animal eyes to make corneal and scleral wounds Practice using the non-dominant hand Practice capsulorhexis in animal eyes Use wax/animal eyes for doing phacoemulsification Able to create trench in nucleus and the chop it into smaller pieces Load and place a foldable IOL in animal eye Practice automated anterior vitrectomy after breaching the capsule in animal eyes
Year 3	<ul style="list-style-type: none"> Experiment with bottle height, vacuum, wound leak, aspiration flow rate, power and different modes in phacoemulsification Thorough understanding of machine parameters Load and place a capsular tension ring in animal eye

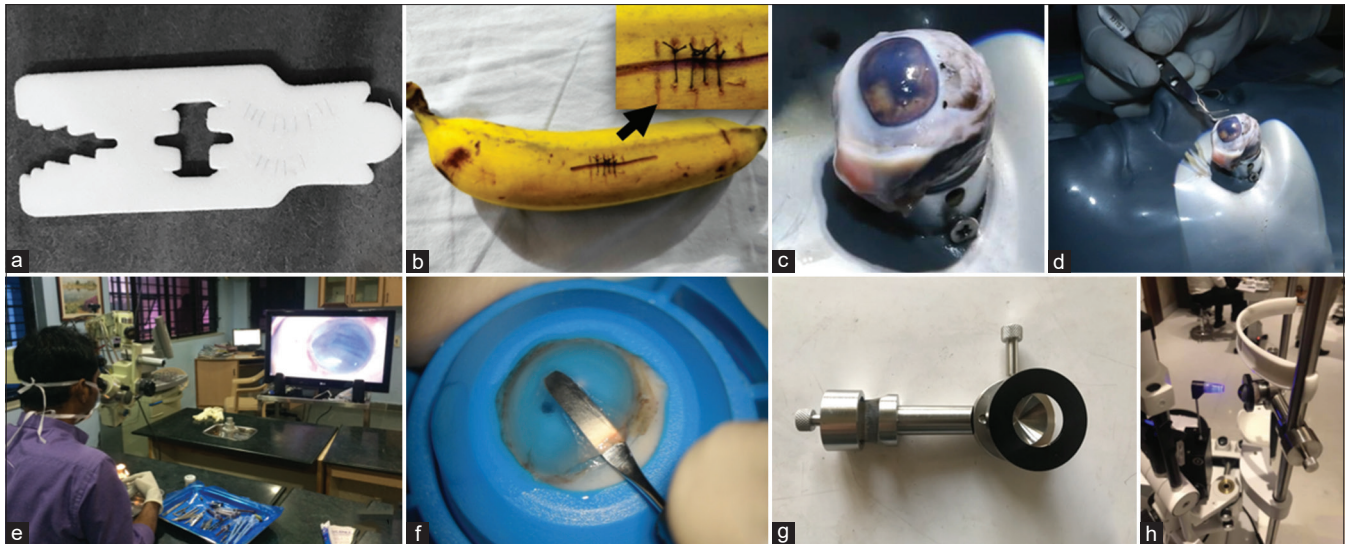


Figure 2: Suturing done on (a) Theraacol, (b) banana, (c and d) use of goat eyes, (e and f) use of unfit donor corneas in wet lab for phacoemulsification and lamellar keratoplasty, (g and h) Fixation of Goat's eye to practice applanation tonometry



Figure 3: (a-c) Spring Action Apparatus for Fixation of Eyeball (SAFE)

Goat's/Porcine eyes [Figs. 2c and d] can also be used. Unfit donor eyeballs/corneas [Fig. 2e and f] can also be used for the same. Porteous *et al.* described practicing Trabeculectomy on Green Apples.^[4] We would recommend at least 50 good radial sutures with proper depth and spacing using 10-0 Nylon, for developing a reasonable degree of confidence in suturing.

Eyeball fixating devices

A properly fixated eyeball is a key ingredient while practicing in the wet lab. Various fixating devices have been described over the years.

Stryfoam head offers a cheap way to stabilize the cadaveric/animal eye into empty eye sockets. However, they lack the stability required and the eye tends to rotate when manipulated. Mathias Zirm also described the use of a similar device simulating the front half of a human head with orbital socket for mounting of the cadaveric eye.^[5] Porello *et al.* used a plexiglass bulb with a polyvinyl chloride pillar as base on a modified polystyrene trial head to secure porcine eyes to perform phacoemulsification, laser iridotomy and argon laser photocoagulation. It reproduced intraocular optics to even

allow clear visualization of the capsular bag. This was, however, a complicated system requiring a setup time between each procedure to setup the eyeball.^[6]

Otto and Mohammadi used vacuum-assisted globe fixation. Otto *et al.* used a funnel and tubing system fitted in a styrofoam head, which allowed variable intraocular pressure control during anterior and posterior segment surgeries. This allowed the residents to practice difficult operating situations like in high intraocular pressure. Mohammadi *et al.* used a cup with an adjustable aperture where vacuum was created at the pre-equatorial area of the eyeball. This was a heavy and complex apparatus with a ballast screwed to end of a cup which allowed automatic repositioning.^[7,8]

The Mandell Practice Eye mount is a commercially available product, which used a syringe & clamp mechanism to maintain globe fixation. It included a plastic eye holder implanted in the center of plexiglass mount, connected to a syringe via a plastic tube with a clamp, which helped to maintain suction throughout. The drawback with this device is that its flat mount does not stimulate correct hand positioning.^[1,9]

Ramakrishnan *et al.* described the Spring Action Apparatus for Fixation of Eyeball (SAFE) which used a hollow iron cylinder attached to the spring action syringe to aid vacuum fixation of the eyeball, along with a masked version device of the same [Fig.3a-c]. This device prevented any globe dislodgement and was even used to facilitate a microkeratome pass while practicing LASIK.^[10]

The i-STAND PLUS Eyeball Stand with Fixation Head (Madhu Instruments Pvt Ltd, New Delhi, India) is a mechanical device which can be used for securely fixing human or animal eyes [Fig. 4a].^[11] The i-MASK Phaco Practice Eyes Fixation Head [Fig. 4b] (Madhu Instruments Pvt Ltd, New Delhi, India) is another commercially available artificial eye (Phaco-i Practice Eyes, Madhu Instruments Pvt Ltd, New Delhi, India) fixator for practicing phacoemulsification [Fig. 4b-d]. Both of these devices are easily available and economically priced. They consist of an artificial head with simulates the facial contours, 2 sockets with screws for globe/artificial eye fixation, a drainage collection tray and a drainage tube.^[11]

Procuring the eye

Rejected/Unfit donor corneas/eyeballs provide the best patient substitute for practicing in the wet lab [Fig. 2e and f] and can be availed from eye banks. Animal eyes (Goat, Pig) [Figs.2c, d and 4a] can be obtained from local butchers. These can be used to practice a huge variety of ocular procedures from trabeculectomy to cataract surgery etc.

Wax/artificial eyes like the PHACO-iPhaco Practice Eyes [Fig. 4c and d] made from a synthetic resin like vinyl, offers a very good option for practicing Phacoemulsification without the messiness associated with human/animal eyes.^[11]

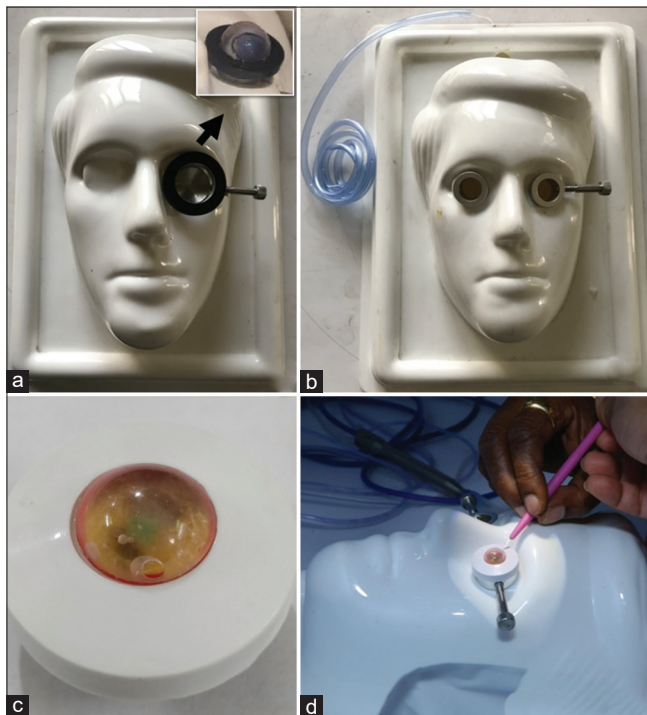


Figure 4: (a) i-STAND PLUS Eyeball Stand with Fixation Head without & with Goat's eye [11], (b) i-MASK Phaco Practice Eyes Fixation Head [11], (c) PHACO-i Phaco Practice Eye [11], (d) Using b and c

Eye preparation

Cataract surgery

Doing cataract surgery in animal eyes can be different than in human eyes due to the difference in anatomy of the two. Capsulorhexis in goat's eyes can be difficult for the beginner surgeon. The lens of a goat is very soft and can only be used to practice trenching in phacoemulsification.^[12] Also, the goat's eye has blue reflex in comparison to the red reflex of a human eye. However, this does not pose much of a challenge.

Pig eyes have a thicker, more elastic and viscous anterior lens capsule, mimicking a pediatric human anterior lens capsule. Various fixatives have been described to stiffen the anterior lens capsule. Henderson *et al.* used trypan blue dye to a mixture of 1:10 ratio to a mixture of equal parts of formaldehyde 37% and any ophthalmic visco-surgical device (OVD) for the same. This can be done before or after filling the anterior chamber with OVD.^[1]

Sengupta *et al.* described a novel technique of practicing phacoemulsification, where a human cataractous nucleus obtained after an extracapsular cataract extraction (ECCE) or manual small incision cataract surgery (MSICS) was inserted in a crater created in a goat's eye capsular bag after debulking its lens matter. The lens thickness of a goat eye lens is about twice as that of an adult human nucleus, thereby allowing easy insertion of the human nucleus into the goat eye capsular bag. Moreover, the lens matter of a goat eye is very soft and is completely cortical in nature, making its debulking an uncomplicated task. The two most important steps while preparing the eye here are the creation of a precise capsulorhexis and construction of crater depth of adequate size to snugly fit the human nucleus, and, hence, the authors recommend these two steps to be done by the trainer until the trainee attains a recommended skill.^[12]

Kayikcioglu *et al.* described a similar technique using Sheep Eyes. Although, they did have difficulty in phacoemulsification due to unstable lens in its capsular bag.^[13] Ram *et al.* and Pandey *et al.* devised surgical wet lab training using the Miyake-Apple technique, where after removal of the cornea & iris at the level of the equator, a glass slide is carefully mounted to the globe remnant using cyanoacrylate glue. However, this allowed open sky phacoemulsification, preventing understanding of a closer chamber phacodynamics. One interesting thing that Pandey *et al.* did was that they injected 0.2 ml of Karnovsky solution intra-lenticularly after continuous curvilinear capsulorhexis and hydrodissection/hydrodelineation in human eyes to increase the density and hardness of the human nucleus. The Karnovsky solution was initially developed by M. J. Karnovsky as a fixative for electron microscopy, which combined the different properties of fixation and penetration of paraformaldehyde and glutaraldehyde, where the former penetrates quickly, but does not preserve tissue well and the latter fixes well but does not penetrate swiftly. It had 2 gm of paraformaldehyde, 2-4 drops of 1M sodium hydroxide, 5 ml of 50% glutaraldehyde and 20 ml of 0.2M cacodylate buffer with pH 7.4. Pandey *et al.* noted that the intra-lenticular injection of Karnovsky solution at multiples sites resulted in nuclear sclerosis (NS) grade 2 after 5 to 10 minutes, NS grade 3 after 15 minutes, NS grade 4 after 20-25 minutes and NS grade 5 after 30 minutes. They used this technique to practice both

phacoemulsification and other manual extracapsular cataract extraction techniques^[14,15] The advantage of practicing with the human nuclei as described above, is that the trainee gets the real like feel of performing phacoemulsification.

The PHACO-iPhaco Practice Eyes to be a useful wax/artificial eye for teaching the basic steps of Phacoemulsification.^[11] After this artificial eye has been used, a human nucleus obtained after an extra-capsular cataract extraction (ECCE) or manual small incision cataract surgery (MSICS) can be put in it, after enlarging the incision using a keratome or lance tip knife, and chopping of phacoemulsification can be done. However, we do recommend to microwave the human nucleus for 10 seconds before using it. This increases the hardness of the lens and making it ideal for learning chopping. This allows the trainee to develop a good hand foot coordination of the phacoemulsification machines and also a better understanding of the chopping techniques in a human/artificial nucleus.

Glaucoma

The same globe fixator of the i-STAND PLUS Eyeball Stand can be modified to be attached to a slit lamp. Applanation tonometry and gonioscopy can then be practiced after fixing a goat's eye to the apparatus [Fig. 2g and h].

Porteous *et al.* developed a novel technique for teaching trabeculectomy by using half cut golden apples. They believed that the consistency of the green apple skin and cortex was similar to that of sclera, and hence could be used to practice scleral flaps. It was very cost-effective and could even be used without a microscope. Later on, the trainees could even practice suturing (interrupted, releasable etc.) on it.^[4]

Vitreo-retinal surgery

Hirrata *et al.* used Japanese quail eggs inside a silicon cap (fashioned like a sclero-corneal cap), with trocars placed in the silicon cap. The yolk and albumen simulated the vitreous body which was removed using a vitrectomy cutter. The inner shell membrane was stained using Brilliant Blue G and membrane peeling was done using vitreous forceps.^[16] We believe the membrane peeling can also be simulated on a chicken egg inner shell membrane, which is easily available everywhere. Alternatively, vitrectomy can also be practiced in Goat's eyes.

Pujari *et al.* described buckling surgery in goat's eye where after mounting the goat eye on the mannequin head. However, this required intact globes with identifiable extraocular muscles. Grossly deformed globes lacking tissue rigidity could not be used in this model.^[17]

Strabismus

White *et al.* used 10 mm width bacon strips to simulate rectus muscles to practice recession surgery in the wet lab, where these strips were secured to styrofoam boards using pins. The trainees could even practice hooking of the muscle, when these bacon strips were secured using full-thickness interlocking bites at either end with 6-0 polyglactin 910 suture. The bacon was then cut from its pin i.e., its insertion. However, this could not simulate muscle isolation.^[18]

Keratoplasty

Donor corneas can be used to practice lamellar keratoplasties after fixing it to an artificial anterior chamber [Fig. 2f]. The

dissected endo-lenticule in case of Descemet's stripping endothelial keratoplasty, can then be secured to the undersurface of another cornea using a sclero-corneal tunnel/corneal incision made on a whole cadaveric human globe. Microkeratome pass for Descemet's stripping automated endothelial keratoplasty (DSAEK) can also be practiced on it. Practicing of the Big Bubble technique, Manual Dissection in Deep anterior lamellar keratoplasty (DALK) can also be done after fixing the donor cornea via the above method.

Famery *et al.* used human donor corneas mounted on an artificial anterior chamber with a 3D printed artificial iris inside to avoid losing the thin endothelial graft into the tubing for practicing Descemet's membrane endothelial keratoplasty (DMEK). It also offered the option of varying the anterior chamber depth while insertion of the graft.^[19]

Refractive surgeries

The microkeratome pass of laser assisted *in situ* keratomileusis (LASIK) can be practiced after securing a donor cornea/cadaveric cornea on an artificial anterior chamber. Ramakrishnan *et al.* described the SAFE device which gave excellent performance for the same.^[10] RELEX SMILE can also be practiced using pig eyes.

Oculoplastic surgery

Coats DK described a using an anatomically correct skull for depicting naso-lacrimal duct surgery. However, this was descriptive only.^[20]

Trauma management

Suturing for sclera and cornea can be practiced on animal/cadaveric eyes.

Virtual simulators

Simulation-based surgical training allows trainees to practice risk free to improve their surgical skills. Previously published articles also suggest simulator training particularly in this COVID-19 era, where the resident training has been affected the most.^[21] Various virtual simulators have been developed by ophthalmic innovators. However, the EyeSi Surgical models have undergone the most comprehensive testing.^[22]

The Eyesi Surgical (VRmagic, Mannheim, Germany) has been extensively used for training of cataract and vitreoretinal surgeries. It consists of a model eye mounted on a mannequin head connected to a microscope with camera & a computer interface. It has internal sensors to track the movements and positions of the surgical instruments, which produces a virtual image which is seen on both the microscope and touch screen. This device even accounts the performance metrics, generating scores and feedback.^[22,23]

The MicroVisTouch (Immersive Touch, Inc, Chicago, USA) consists of a robotic arm having a handpiece which is used to control the instrument being used in the simulation. This simulator has a unique advantage that it has a tactile feedback interface. Its limitation is that it is restricted to only clear corneal incision, capsulorhexis & phacoemulsification.^[22-27]

Phacovision (Melerit Medical, Linköping, Sweden) is a 3D personal computer with a handpiece for phacoemulsification, a nucleus manipulator, foot pedals and microscope. Other devices for phacoemulsification include the Phantom Phaco-simulator and the cataract surgery simulator.^[22,28-30]

HelpMeSee Eye Surgery Simulator (HelpMeSee Inc, New York, USA) combines realistic computer graphics and physics modeling with motion sensors and tactile feedback to create an excellent environment for repeatedly practicing all the steps of manual small incision cataract surgery. It also maintains an objective measurement & recording of the trainee's surgeries, while documenting their skill level through different phases of their learning.^[21,31]

Vitreo-retina simulators include the Pars plana vitrectomy simulator, Sophocele, VR surgery simulator, Vitrectomy simulator and the Vitreous surgery simulator. While the Sophocele focuses on Retinal Photocoagulation, other are inclined towards doing Vitrectomy in an artificial environment.^[32-36]

Merril *et al.* have also described the Ophthalmic Retrobulbar Injection Simulator (ORIS), which allowed the trainees to practice retrobulbar anesthesia injection, using real-time computer-generated graphics.^[37]

LASER-i (Madhu Instruments Pvt Ltd, New Delhi, India) is an ophthalmic teaching device which can be used to simulate red/green laser shots in an artificially diseased retina. Its optics resemble that of an aphakic, emetropic eye.^[11]

Mustafa *et al.* developed a 3D ocular model to teach ophthalmic ultrasound to a trainee. The model generated video clips which simulated movements and orientations of the scanner head. It was used to help develop spatial awareness and its adaptation in clinical practice. It also helped with localization of the lesions for diagnosis, measurements and reporting.^[38]

Diagnostic virtual simulators have also been described in literature. The Eyesi Direct Ophthalmoscope (VRmagic, Mannheim, Germany) allows retina evaluation using an ophthalmoscope handpiece and model head connected to a built-in display. This aims to teach Direct Ophthalmoscopy to the trainee.^[23,39] The Eyesi Indirect Ophthalmoscope (VRmagic, Mannheim, Germany) consists of an ophthalmoscope headband which is to connected patient model head and also has a built in computer display. This aims at teaching Indirect Ophthalmoscopy to the trainee.^[23,40] MODEL-i (Madhu Instruments Pvt Ltd, New Delhi, India) is an excellent model for practicing indirect ophthalmoscopy and retinoscopy, where normal & abnormal structures are painted inside the eye. It can simulate both myopic and hyperopic eyes.^[11]

Computer and surgical video viewing station

A wet lab needs to have a desktop computer where a trainee can review his/her surgeries and also look at surgeries done by expert surgeons. It needs to have internet access to allow him/her to check for the same online as nowadays there are multiple websites which offer the same. The presence of a video editing software on this computer will be beneficial to the trainee, as while video editing he/she will look at the finer details/mistakes during the surgery.

Responsibility and ownership

The wet lab is intended for the trainee and we would recommend the second-year residents to take responsibility of it in monthly rotations. The second-year resident would have just started microsurgery in the operating room and at the

same time would be spending quite a lot of time in the wet lab. At the same time, he/she would have more knowledge than a first-year resident, which would be required. Thus, it would be ideal for him/her to take charge of it. However, he/she should report to the consultant-in-charge of the wet lab.

Financial backing

This is arguably the most difficult part of setting a wet lab, as the cost of equipment required for it could be a bit high especially if we go for simulators. One can use older phacoemulsification machines. Grants from various sources do help for the cause. For financially challenged institutes, the option of collaboration with neighboring medical colleges/training programs is always a cheaper option or can start basic settings with Indian made table mount microscope and 1–2 eye fixator/holding stands. One can also tie up with pharma companies who sometimes run their cataract training programs in association with an institute. Unsterile sutures are good option to reduce cost in cases of PK/Suturing wet lab training.

Conclusion

A wet lab is the fundamental ingredient of resident surgical training program, as it provides a stress-free environment for the trainee to hone his/her surgical skills. Human donor/animal (goat/pig)/artificial eyes can be used by them to practice various types of surgical procedures before operating on a real patient. Virtual simulators do hold a strong future in resident surgical training, but more development in them needs to occur for them to be widely accepted. We believe this article focusing on essentials of setting wet lab training will help both the institute/center and trainee to create a risk-free, exemplary platform to master the surgical and clinical skills, which will be especially useful in times of a global or national pandemic.

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Conflicts of interest

There are no conflicts of interest.

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