Simulated ocular surgery: pars plana vitrectomy and scleral buckling surgery

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In this second article on ocular surgery simulation, we will discuss how vitreoretinal surgery can be simulated using high tech virtual reality modalities such as the Eyesi, as well as other lower tech but very versatile platforms such as model eyes. The first part of the article will focus on pars plana vitrectomy simulation and then we will discuss simulated scleral buckling surgery.

Vitreoretinal (VR) surgery is different to other forms of intraocular surgery in several respects. Firstly, vitreoretinal surgery is usually more technically challenging and involves more intricate steps, compared to, for example, cataract surgery. Secondly, as a vitreoretinal surgeon, one needs to have a detailed knowledge of the technology used during surgery, such as vitrectomy machine parameters, fluidics, intraocular tamponade, etc. Additionally, the likelihood that surgery will become more complicated or that the surgeon will face unanticipated situations, is higher in vitreoretinal surgery than most other forms of ocular surgery. Taken together, these factors underscore the importance of simulation training in VR surgery to teach technical skills and even more importantly to hone the surgeon's ability to deal with evolving and unexpected situations.

Pars plana vitrectomy

The Eyesi VR module allows simulation and the objective assessment of many of the steps involved in pars plana vitrectomy (PPV) surgery. Just like in the cataract module, each task is objectively scored, giving simultaneous feedback and a detailed score looking at various aspects of the manoeuvre such as microscope and instrument handling, economy of movement, and completion of the task without causing inadvertent tissue damage (Figure 1).

One of the most important and realistic aspects of vitrectomy surgery that can be practiced and tested with the Eyesi is the X-Y movement of the microscope in concert with movement of the eye. This is much more necessary in vitreoretinal surgery than other forms of intraocular surgery, because of the need to obtain an optimum view of the peripheral retina that can only be achieved by movement of the eye and microscope together in the same direction. This step needs a lot of practice by the vitreoretinal trainee until their ability to maintain a centralised view becomes 'second nature'. The Eyesi tries to establish this skill and will penalise surgeons who fail to move the eye and microscope together and can actually prevent progression through the various stages until this skill is honed.

When learning to perform vitreoretinal surgery, trainees need to develop a sense of awareness of instruments, position in the eye relative to intraocular structures. This could take time and often complications such as inadvertent retinal touch or crystalline lens injury are encountered more frequently in the learning phase. Training on the Eyesi can help the trainee to develop this skill by simulating and recording damage to intraocular structures as they occur. For example, crystalline lens touch if instruments are reached too far across the midline and bleeding of the retina if it is inadvertently touched.

Vitreoretinal surgery requires a high degree of manual dexterity. The Eyesi forces the surgeon to use their non-dominant hand to perform manoeuvres, encouraging the flexibility that is often required. The initial stages of the vitreoretinal module helps the surgeon to become familiar with using bimanual techniques with various abstract tasks, and then progress on to manoeuvres that are actually required during vitrectomy, such as induction of posterior vitreous detachment with the cutter, cutting structures close to the retina with the scissors (Figure 2) to simulate segmentation and delamination steps, using forceps to peel membranes and appropriate use of the endolaser (Figure 3).

The other method for teaching PPV using simulation is model eyes. The simulated ocular surgery model eyes have been refined over a 15-year period by Craig Phillips (Phillips Studios), using a variety of materials that accurately replicate the look and, more importantly to a higher degree, the feel of a human eye. The eyes developed for pars plana vitrectomy are hollow from inside and could be filled with egg white to simulate human vitreous (Figure 4).

Simulation of vitrectomy with the model eyes not only complements training achieved through practicing on Eyesi, but also offers additional advantages through providing a more realistic and versatile simulation experience in learning pars plana vitrectomy than the Eyesi, with the added benefit of being much cheaper and more readily available. Creation of vitrectomy ports (Figure 5) and suturing them, as well as inserting the infusion cannula are very basic and essential skills that trainees need to learn at the beginning of their vitreoretinal training and cannot be taught using the Eyesi but could easily be practiced on model eyes.

The model eye can also simulate manoeuvres such as removal of the egg white 'vitreous' with a vitrectomy cutter and light pipe or even peeling simulated epiretinal membranes, or insertion of a scleral buckle during vitrectomy. Removal of a dense vitreous haemorrhage can also be simulated by adding red food dye to the egg white (Figure 6). These forms

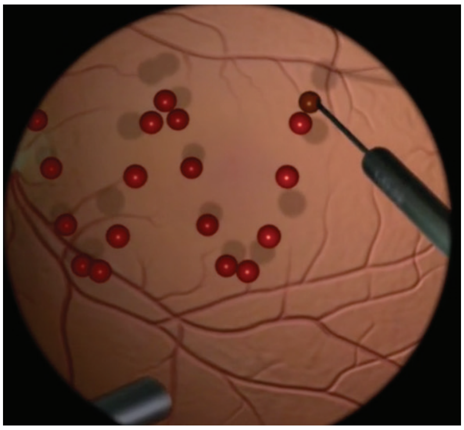

Figure 1: Eyesi abstract task.

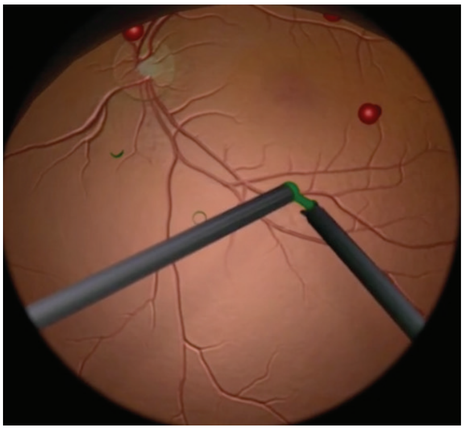

Figure 2: Ocurring structures close to the retina.

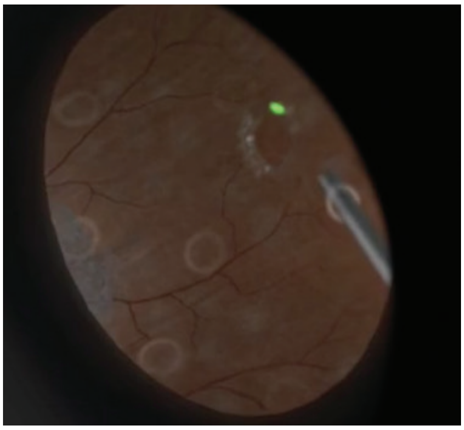

Figure 3: Eyesi endolaser.

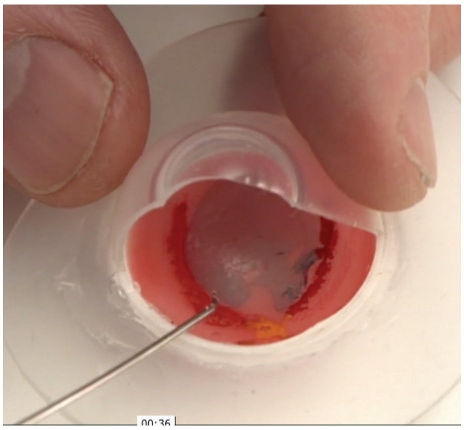

Figure 4: Vitrectomy eye with ERM.

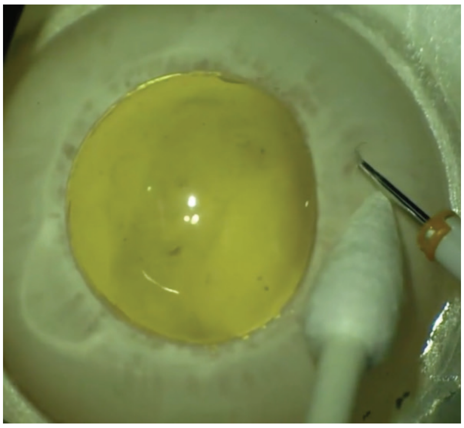

Figure 5: Inserting scleral ports.

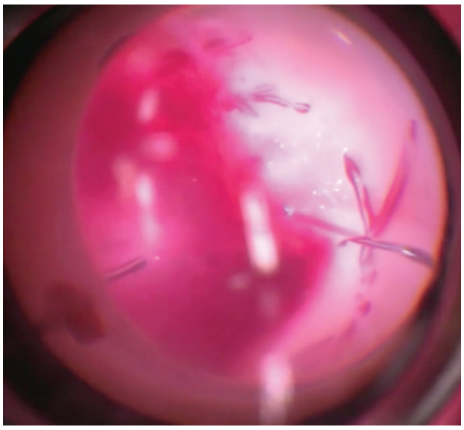

Figure 6: Vitrectomy for vitreous haemorrhage.

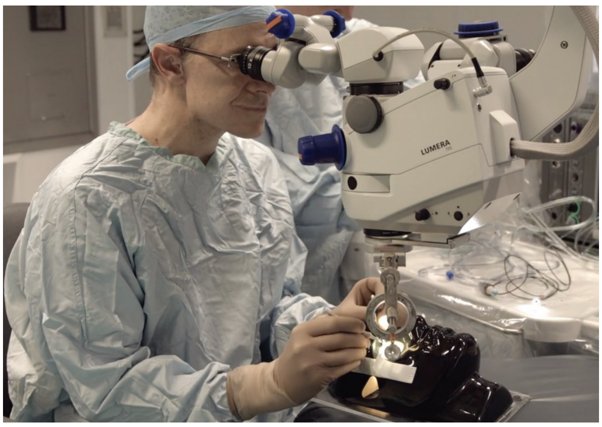

Figure 7: SOS vitrectomy simulation.

Figure 8: Basic scleral buckling eye.

of simulation enable trainees to become familiar with the vitrectomy machine, light pipe, cutter, operating microscope and wide angle viewing system or contact lens, which they will be using for live surgery (Figure 7).

Unplanned events and intraoperative complications during vitreoretinal surgery represent a challenge for the accomplished vitreoretinal surgeon, let alone the novice one. It is much better that surgeons are trained to deal with these events away from patients but in an environment that is close to real-life. The use of model eyes provides such a valuable experience. For example, the mentor can pull the infusion cannula out of the eye and get their student to identify the source of hypotony and then teach them how to best and efficiently manage this situation.

Currently, Phillips Studios is working on the development of a model eye which can be used to practice indirect and endolaser techniques. This is a very welcome addition, particularly as mastering indirect laser is not a very straightforward skill to learn and does require a lot of practice, discussion and advice to optimise the technique. The eyes showcased on the Simulated Ocular Surgery website have been used for teaching all over the world by trainees for solo practice and in workshops and training courses, including the Duke University Advanced Vitreoretinal Course in the US.

Scleral buckling

There are two types of model eyes than can be used to simulate scleral buckling (SB) surgery:

1. The basic vitreoretinal eye: this model eye has no conjunctiva nor Tenon's capsule. It has four rectus muscles but has no oblique muscles. The globe is hollow, and has an internal 'retinal tear' that can be seen with an indirect ophthalmoscope and is the target location for the scleral buckle (Figure 8). The sclera has been made out of a material that has the same resistance to a needle pass as human sclera and has a similar tensile strength, so sutures will not cut out of the sclera, but will cut out if the scleral pass is too shallow.
2. The advanced eyes: these have the same retinal tear, scleral shell and rectus muscles, but they also have a layer of conjunctiva, with similar elastic properties of human conjunctiva and a layer of Tenon's capsule.

The use of simulation to learn SB is, in our view, a highly desirable step for every vitreoretinal trainee for a variety of reasons. Firstly, data from the UK shows a steady decline in the number of SB operations performed in the UK in the last 15 years [1]. This trend has also been seen worldwide [2-3]. The paucity of SB cases means that trainees will not have the chance to properly develop the skills required for this surgery. Simulation is therefore very important to make sure that a trainee has practiced these techniques in a safe environment, has demonstrated their competence and can therefore take advantage of the opportunities to perform SB surgery when they arise. Secondly, in the era of small incision cataract surgery, trainees do not have many opportunities to hone their tissue dissection and suturing skills, and even if they are not going to become vitreoretinal surgeons these skills will stand them in good stead for whatever branch of ophthalmic surgery they specialise in. In addition, many quite senior trainees feel outside their comfort zone when performing an indentation examination of the eye with the indirect ophthalmoscope (Figure 9) and improving these skills to the point where they do not have to consciously think which direction to move the indentor will improve their preoperative assessment of patients, as well as their surgical technique in theatre.

When teaching our trainees to perform SB on model eyes, we use the basic eye to practice locating the retinal break by indentation examination with an indirect ophthalmoscope and marking the break location on the outside of the eye, placing sling sutures around the rectus muscles, scleral buckle suturing and knot tying at the appropriate tension to create an adequate indent (Figure 10). All of which allow the trainee to get a feel for the tissues and build up their confidence with these manoeuvres. This is best done initially in a one to one setting with the trainer, after which the trainee can take the head and eyes home to practice. Once they have mastered these basic skills we move on to placing larger buckles, encircling bands (Figure 11) and how to drain subretinal fluid or inject a gas bubble, again with one to one instruction followed by solo practice.

To help with assessing a trainee's progress towards competence we have designed an Ophthalmic Simulated Surgical Competency Assessment

Figure 9: Practising indentation.

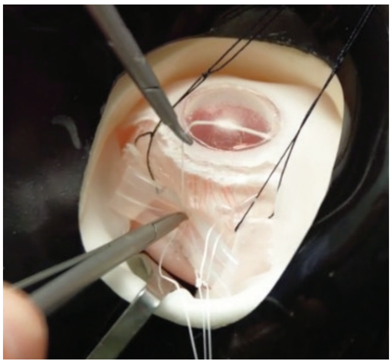

Figure 10: Suturing a scleral buckle.

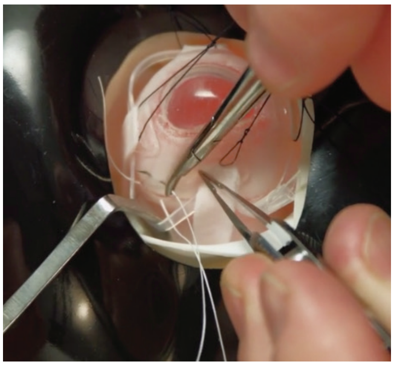

Figure 11: Suturing an encircling band.

Rubric (OSSCAR) for SB surgery. The scoring system is self-explanatory and includes a global assessment of tissue handling, instrument handling and knot tying. A PDF of this OSSCAR can be downloaded from www.simulatedocularsurgery.com

In a similar way to how we teach cataract surgery, VR mentors can build up to teaching the whole operation by breaking down the procedure into blocks of two to three steps, and when a trainee is achieving a competent level for these blocks they can start practicing under supervision on patients. As their confidence and competence grows, they can string together more stages of the operation until they can perform the complete procedure.

The other important skill that can

be taught using simulation is the art of being a good surgical assistant. Knowing how to create good exposure of the surgical site, how to hold squint hooks correctly so that your hands are not getting in the way of the principle surgeon. It is needless to say that a good assistant makes an excellent future surgeon.

In summary, the Eyesi provides a fantastic simulation tool for teaching PPV. However, not all trainees will have access to this expensive technology, and in some respects, simulation of vitrectomy with model eyes complements training on Eyesi for certain steps of the surgery, as well as provides a realistic and versatile simulation experience for the trainee. Scleral buckling is a procedure that can only be simulated using model eyes and owing to the decline in number of scleral buckling surgeries performed, simulated scleral buckle surgery should be an integral part of all VR training programmes.

Finally, it is worth mentioning that, for experienced VR surgeons, simulation can also play a role in further improving their surgical skills, particularly when trialling new instruments such as surgical endoscopes or learning emerging techniques that are not routinely performed, for instance, macular buckling. In addition, experienced surgeons who take time out from operating because of illness, injury, maternity or academic reasons can use the model eyes to regain their previous skills.

More detailed descriptions of all of these simulation techniques can be found on the Simulated Ocular Surgery website.

References

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Declaration of Competing Interests
None declared.

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