The Hull Anterior Vitrectomy Simulation System (HAVSS): a validated novel simulation for training in the management of intra-operative vitreous loss

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Abstract

Objectives To design and validate a feasible simulation to address an identified training gap in the management of intraoperative vitreous loss.

Methods Our simulation consists of a two-part non-toxic mixture that polymerises upon contact within a silicone training eye, to resemble the appearance of vitreous after staining with triamcinolone. This gel can be cut and aspirated with an anterior vitrectomy probe. Experienced consultant ophthalmic surgeons were invited to assess the simulation and anonymously complete validity questionnaires.

Results Seven senior surgeons participated. Four (57%) strongly agreed and three (43%) agreed that the tissue behaved like vitreous. Six (86%) strongly agreed and one (14%) agreed that instrument handling was realistic. Three (43%) strongly agreed and four (57%) agreed that simulated triamcinolone staining was realistic. Four (57%) strongly agreed and three (43%) agreed that the simulation was visually convincing. Six (86%) strongly agreed and one (14%) agreed that this simulation is useful for training. No participants disagreed with any validity statements.

Conclusions This novel simulation of anterior vitrectomy has good face and content validity, with unanimous agreement among experienced surgeons of its utility for training in the management of intraoperative vitreous loss.

Introduction

Vitreous loss, most often due to posterior capsule rupture, is an intraoperative complication of cataract surgery that is a source of anxiety for surgeons in training. Although the incidence of posterior capsule rupture with vitreous loss is <2% in the United Kingdom [1], if it occurs it is associated with an increased risk of a poorer outcome due to secondary complications, such as cystoid macular oedema, retinal detachment and endophthalmitis [2]. This risk is mitigated if vitreous loss is promptly recognised and appropriately managed.

Intraoperative vitreous loss can be managed safely by performing a careful anterior vitrectomy to remove all prolapsed vitreous humour from the anterior chamber. The procedure can be challenging due to the difficulty in visualising transparent vitreous gel. The use of triamcinolone to delineate vitreous, first described by Burk et al., permits a more thorough and precise removal with fewer unnecessary manoeuvres [3]. It is increasingly recommended by trainers in teaching and discussions about cataract complications.

In the United Kingdom, ophthalmologists in training are expected to meet minimum standards of competence in cataract surgery set by the Royal College of Ophthalmologists (RCOphth) in order to complete the seven-year ophthalmic specialty training (OST) programme [4]. These standards are quantitative: Trainees must have logbook evidence of at least 350 complete phacoemulsification procedures, including a visual and refractive outcomes audit of 50 consecutive cases. It is also compulsory to declare complication rates, defined as the percentage of cases in which posterior capsule rupture with vitreous loss occurred. The curriculum states that a good case-mix is expected and

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Table 1 Composition of component mixtures for simulation of vitreous and triamcinolone. Brand information of items used in this study are listed at the bottom.

Component	Part A	Part B
Preparation	Two parts of 0.4% w/v aqueous solution of sodium alginate ^a with 1 part liquid egg white ^b	Aqueous solution of 4% w/v calcium chloride ^c and 2% v/v white watercolour paint ^d
	^a Algin Textura, Sole Graells, Spain.	
	^b Two Chicks®, UK.	
	^c Calcic Textura, Sole Graells, Spain.	
	^d Chinese White, Winsor and Newton™, UK.	

specifies the management of intraoperative and post-operative complications as a learning outcome. This could be assessed by means of objective structured assessments of technical skills, but competence in managing specific complications is not necessarily measured or verified. The use of simulation for cataract surgery training is strongly encouraged by the RCOphth [5]. Several wet-lab and virtual reality simulations for the practice of phacoemulsification techniques are available across training centres in the United Kingdom. However, at the time of writing, an expert-validated simulation does not exist for training in the management of intraoperative vitreous loss. With this in mind, the authors decided to ascertain the need for such training and design a simulation for this skill, including visualisation of vitreous with triamcinolone.

Materials and methods

As this work was not a research study involving patients or service users, institutional review board approval was not required.

Needs analysis

A web-based survey was created and distributed by email, asking senior trainees (OST years 3–7) in the authors' training region to anonymously report their experience in performing anterior vitrectomy for vitreous loss, including assistant and supporting roles. They were also asked whether or not current exposure to training in this skill was adequate. Free-text space was provided for additional comments. The survey was closed after 1 month and responses collated for analysis.

Design of simulation

We designed a non-toxic two-component mixture to simulate vitreous and triamcinolone. The composition of each component is detailed in Table 1. Part A was prepared by first dissolving sodium alginate in water using an electric hand blender, then allowed to stand to clear bubbles. Liquid egg white was then carefully added to the alginate solution with minimal agitation to prevent foaming of egg white.

Fig. 1 Simulation station set-up. **a** Training eye secured in holder. Syringe seen below, containing part A. **b** Lateral view of set-up. Syringe is connected via a butterfly needle with wings clipped.

Part B was made by preparing an aqueous solution of calcium chloride and white watercolour paint in the proportions described.

A defect was made in the posterior capsule of a silicone cataract surgery training eye (Phillips Studio UK). The posterior segment of the training eye was filled with Part A of our two-component mixture (Table 1). A continuous supply of Part A was connected to the training eye by a syringe to allow additional filling if needed. Figure 1 shows the set-up, assembled ready for use. A syringe with a Rycroft cannula was used to introduce 'mock' triamcinolone, Part B of the mixture (Table 1), into the anterior chamber through a corneal paracentesis. Displacement of the sodium ions in Part A by calcium ions from Part B led to

Fig. 2 Microscope view of training eye. **a** A posterior capsule defect has been made and transparent vitreous (part A, from the concealed syringe) has entered the anterior chamber. **b** Following injection of

part B ('mock' triamcinolone) into the anterior chamber and precipitation of white stained strands (arrow) of calcium alginate, the polymer can be removed using a vitrectomy cutter.

the formation of strands of insoluble calcium alginate gel that were stained white from the watercolour paint in Part B. A 20-gauge anterior vitrectomy cutter (Bausch & Lomb Stellaris BL5612), introduced through the main cataract incision, was used to remove this polymer from the anterior chamber using standard aspiration and cut-rate settings. Anterior chamber stability was maintained by an irrigation hand-piece through the paracentesis. Figure 2 shows the appearance of the simulated vitreous before and after 'mock' triamcinolone staining.

Validation of simulation

Consultant ophthalmologists with expert-level experience in cataract surgery were invited to test the simulation in the skills training lab. All participants were from a single centre. The authors of this project did not participate in the validation exercise. Gloves and standard ophthalmic instruments were provided, and standard operating equipment—a Haag-Streit (Allegra) operating microscope and a fully functional Bausch & Lomb Stellaris phacoemulsification machine were provided. For each tester, the training eye was set up as described above, with the lens nucleus already removed and a defect made in the posterior capsule. Testers attended individually and performed the procedure uninterrupted. The details of the contents and construction of the simulation were not disclosed. Following testing, participants were each asked to anonymously complete and submit a validation questionnaire containing six statements to be rated on a 5-point Likert scale.

Results

Needs analysis

Twenty-one senior trainees (OST years 3–7) responded to the training survey. Distribution of respondents by year

group is shown in Fig. 3a. Fifty-three percent of respondents had already achieved the RCOphth minimum of 350 complete cataract cases (Fig. 3b). The majority of trainees reported performing a total of five or fewer anterior vitrectomy procedures in their training to date (Fig. 3c). When asked whether current access to practical training in the management of intraoperative vitreous loss is adequate, 19 trainees (90.5%) responded in the negative. The two trainees who felt access to training was adequate were final-year (OST7) trainees, one of whom had completed an immersive 12-month vitreoretinal subspecialty placement.

Validation of simulation

Seven consultant ophthalmic surgeons attended individually to test the simulation. All seven agreed or strongly agreed with statements about the face, content and training validity of the simulation. There were no neutral or disagreement responses to any of the statements on the validation questionnaire. Figure 4 shows the responses to each Likert item.

Discussion

Needs analysis

The majority of trainees had completed the minimum number of phacoemulsification procedures required for completion of training, yet most did not have extensive experience of performing anterior vitrectomy in the context of intraoperative vitreous loss. The revelation that an overwhelming majority of trainees did not feel that training in this technique was adequate highlights an important learning gap, as trainees are expected to achieve competence in the management of intraoperative complications by completion of training [4]. Our findings mirror the results of a similar survey of London trainees in 2016, in which <10% felt confident managing vitreous loss unsupervised [6].

Fig. 3 Trainee survey data. **a** Distribution of survey respondents by training year. **b** Trainee self-reported totals of cumulative cataract surgery experience. **c** Trainee self-reported experience of performing anterior vitrectomy in the context of intraoperative vitreous loss.

Design and validation of simulation

The results of our validation study clearly demonstrate strong face, content and teaching validity for this simulation. One of the main strengths of our study is that we exclusively recruited expert senior surgeons to participate in the validation exercise. To our knowledge, at the time of writing, there are no other simulations of anterior vitrectomy in the published literature that have had their validity formally tested

by expert cataract surgeons. However, we acknowledge that this necessarily limits the size of our participant pool.

Our design was borne of a search for a simple yet realistic simulation for anterior vitrectomy. The practice of using egg white alone to simulate vitreous already exists in current training [7]. However, in our experience, we found that egg white can be aspirated very easily, and its successful removal from the training eye does not require the use of the cutter. This runs the risk of novices becoming habituated to removal of vitreous by aspiration without cutting and not recognising the adverse effect of this, namely traction leading to retinal detachment and macular injury.

A second published candidate for vitrectomy simulation is the use of Crazy Slime (Out of the Blue, Germany), as described in the Queens Hospital Model [8]. While we agree that this substance has convincing elasticity similar to vitreous, its bright colour means the learning curve of visualising vitreous is not addressed and the appearance is less realistic. A colourless version is not available in the market. Furthermore, on our attempts, its use led to irreversible obstruction of the vitrectomy cutter, rendering the instrument single-use, which would not be economically viable for training provision.

A third model that has recently become commercially available is the SimulEYE A-Vit model, (InsEYE LLC, California, USA) [9]. This is a single-use simulation and would thus lead to greater expense if used for regular training and practice.

In contrast, our simulated vitreous is initially colourless and difficult to visualise, as is often the case in the real intraoperative situation. The polymerisation reaction permits realistic visualisation mimicking triamcinolone staining, encouraging trainees to adopt triamcinolone visualisation into their standard practice. The simulation is quick to assemble, and the components are portable, non-toxic and inexpensive. The component Part A can be frozen for storage and is just as effective when used after thawing. The stained alginate polymer can be removed only if a cutter is used, at typical cut rates for anterior vitrectomy. Aspiration alone will not remove it and will visually simulate traction. This therefore encourages good practice by reinforcing the learning point that aspiration without cutting is an unsafe practice. Finally, the simulation is designed for use with real surgical equipment and instruments, which are easily sourced and replaced. Each training eye can be refilled and used several times in a training session. The polymer does not cause damage or obstruction to the cutter or other instruments, so these can be reused, thus reducing both the running cost of training activities as well as waste generation.

The main drawback of this design is that the preparation of component stock solutions must be done with accuracy, to ensure the correct consistency when the polymer forms in

Fig. 4 Expert responses rating face, content and training validity of simulation following testing exercise.

There were no neutral or disagreement responses (these options were available for selection on the questionnaire).

real-time. In our experience, the presence of egg white in the mixture is essential, as it confers some elasticity and fluidity to the resulting gel compared with alginate alone, but its inclusion renders Part A perishable or susceptible to microbial growth. This solution must therefore be kept refrigerated and used within a week of preparation or thawing, after which it must be discarded appropriately. To minimise waste, we advise preparing Part A in smaller aliquots and making use of its amenability to frozen storage.

As with any skills simulation, we advocate the use of the above as a learning tool rather than a substitute for traditional training by expert professionals. Its potential will be maximised if it is used to practise the skill of anterior vitrectomy with adequate instruction and supervision by experienced surgical trainers.

Since developing our simulation we have incorporated it into our regional advanced cataract courses on multiple occasions, and have demonstrated Kirkpatrick level 2 training efficacy by measuring a statistically significant increase in trainee self-reported confidence after using our model, compared to pre-course confidence [10]. Our next steps will be to assess long-term retention of skills and confidence by trainee surgeons following the use of our simulation, to demonstrate Kirkpatrick level 3 efficacy. Additional future work will include the validation of this simulation for posterior segment vitreoretinal procedures.

In summary, we share our design of a useful, validated and affordable simulation for anterior vitrectomy in the management of intraoperative vitreous loss, and encourage our colleagues in ophthalmic surgery to consider adopting it into their local training repertoires.

Summary

What was known before

- Vitreous loss is known complication of cataract surgery can be managed by performing an anterior vitrectomy.
- Ophthalmology trainees in the UK are expected to complete their training with a good case-mix in cataract surgery and experience in management of complications.
- Trainee confidence in the management of intraoperative vitreous loss has been reported as low.

What this study adds

- There is a clear need for practical training, in a safe and controlled environment, in the management of intraoperative vitreous loss.
- We share an affordable, novel and validated simulation that can be adopted in training units to address this need.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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References

1. National Ophthalmology Database Audit. Year 3 annual report—the second prospective report of the National Ophthalmology Database Audit. 2018. <https://www.nodaudit.org.uk/u/docs/20/mgishnmlhq/NOD%20Audit%20Annual%20Report%202018.pdf>. Accessed 12 Nov 2018.
2. Jacobs P. Vitreous loss during cataract surgery: prevention and optimal management. *Eye*. 2008;22:1286–9.
3. Burk S, Da Mata A, Snyder M, Schneider S, Osher R, Cionni R. Visualizing vitreous using kenalog suspension. *J Cataract Refract Surg*. 2003;29:645–51.
4. The Royal College of Ophthalmologists. Curriculum for ophthalmic specialist training—surgical skills SS4. 2018. <https://www.rcophth.ac.uk/learningoutcomes/ss4/>. Accessed 12 Nov 2018.
5. Simulation in Training. The Royal College of Ophthalmologists. 2018. <https://www.rcophth.ac.uk/training/ost-information/simulation/>. Accessed 12 Nov 2018.
6. Turnbull A, Lash S. Confidence of ophthalmology specialist trainees in the management of posterior capsule rupture and vitreous loss. *Eye*. 2016;30:943–8.
7. Larry B, John F. Feature: simulated ocular surgery. *Eye News*. 2019. <https://www.eyenews.uk.com/features/ophthalmology/post/simulated-ocular-surgery>. Accessed 12 Nov 2018.
8. Wawrzynski J, Zygoura V, Paul B. The Queens Hospital model for simulated anterior vitrectomy: a pilot study of a novel wetlab training tool amongst UK ophthalmology residents. Poster presented at the XXXIV congress of the European Society of Cataract and Refractive Surgeons, Copenhagen, Denmark, 10–14 Sep 2016.
9. SimulEYE A-Vit. SimulEYE Ophthalmic Surgical Training Models. 2019. <https://www.simuleye.com/products/simuleye-a-vit>. Accessed 15 Jul 2019.
10. Hom-Choudhury A, Innes J. Novel validated simulations to bridge an identified training gap in the management of complex cataract surgery cases. Poster presented at the 7th annual conference of the Association for Simulated Practice in Healthcare, Bristol, United Kingdom, 15–19 Nov 2016.