Development of a low-cost strabismus surgery simulation model: Face and Content validation

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Conflict of Interest

There are no direct benefits to the research participants or study authors.

Abstract

Background/Objectives: Strabismus surgery training has historically focussed on the “see one, do one and teach one” approach. Simulation training offers an alternative to practice surgical skills without direct patient involvement. However, current simulation models for strabismus surgery are limited due to concerns regarding use of animal or human tissue and financial cost limiting practice. Our aim was to build and validate a low-cost model for obtaining the core skills required in strabismus surgery.

Subjects/Methods: A low cost strabismus model was developed using commercially available materials. Ophthalmic trainees, fellows and consultants were surveyed using a questionnaire to assess the realism and training utility of the model using a 5-point Likert scale (1 = unacceptable, 2 = poor, 3 = acceptable, 4 = favourable and 5 = excellent) whilst simulating a horizontal muscle resection task.

Results: 42 ophthalmologists completed the questionnaire. The model scored highly for muscle securing (mean 4.29) and suturing (mean 4.24). Muscle dissection and conjunctiva were considered poor (mean 3.24, 2.42 respectively). Overall, participants felt the model simulated strabismus surgery well (mean 3.93) and was comparable to other dry simulation models (mean 3.91).

Conclusion: Our study validates the training model, which can be used for independent practice of core strabismus surgical techniques. However, it remains a technical challenge to replicate certain ocular tissues using commercially available materials.

Summary

What is known?

- Ophthalmic surgical training has evolved to focus on key competency acquisition, with minimum procedural numbers required by completion of training
- Extraocular muscle surgery is an important multi-disciplinary skill for ophthalmic trainees for strabismus correction and other procedures e.g. orbital surgery, scleral buckling, enucleation and globe repair.
- Simulation training with models show promise in aiding surgical skill acquisition.
- There is limited data published on strabismus surgery training and model validity.

What does this paper add?

- We validate a low-cost strabismus surgical training model, easily constructed with commercially available materials.
- Our model performed especially well for muscle securing and suturing which are the most critical steps in strabismus surgery.
- This model can be created at home to allow flexible training suited to the individual trainee to practise and develop core strabismus surgical techniques.

Introduction

Ophthalmic surgical training programmes aim to develop trainees' level of proficiency within in the various subspecialties of ophthalmic surgery. These include extra-ocular muscle surgery, primarily for strabismus correction, but also as part of enucleation, retinal detachment and repair of globe trauma. The ophthalmic speciality training curriculum in the United Kingdom requires trainees to have completed twenty surgical strabismus procedures by time of completion of training (ref. 1). Of these five may be simulated as long as they are observed.

Surgical training has evolved within the last few decades from the traditional Halsteadean approach; "see one, do one and teach one" (ref. 2), to a competency-based framework (ref. 3) in recognition of the learning curve of skills acquisition. However, acquiring the required competencies within the postgraduate training programme remains a challenge. This is due to legislative and regulatory contractual changes in favour of minimising fatigue and improving patient care (ref. 4). Perhaps reflected in current training, there is a declining trend in speciality surgical experience at time of completion of training (ref. 5).

The challenge of any learning curve is to allow development of skills during the novice phase, which is prone to greater risks, without compromising outcome e.g. inadvertently perforating the globe in cases of strabismus surgery. There is sparsity of published data on the strabismus surgery learning curve. Kim et al, report that 20-40 cases are required to obtain efficiency and proficiency of performing horizontal single muscle surgery (ref. 6), however, this is related to the learning curve of an established ophthalmic surgeon that has acquired technical skills in ophthalmic surgery. This is further compounded by the emotional state of the trainee; one survey of ophthalmology residents found poor recall of learning due to anxiety from conventional operative strabismus surgery teaching experience, which resulted in a negative performance (24% reporting tremor, 11% had tachycardia, 10% moments of absence and 34% felt nervous) (ref. 7).

Simulation training has shown promise in technical and non-technical skills training (ref. 8,9) to bridge the learning curve. Despite the proven benefits, very few simulation models have been formally validated in ophthalmology (ref. 10). Current high-fidelity simulation training in strabismus surgery is available with the use of cadaveric tissue (human, rabbits or porcine) (ref. 11). However, this is expensive, provides single on-off simulation experience or requires specialist licencing for training. This is not ideal, as it creates an elite model for training limited to centres that can provide the necessary resources.

Aim

Our aim was to develop and validate an alternative simulation model using low cost materials to allow practice of basic surgical skills required for strabismus surgery.

Method

Low-Cost Strabismus Model

Various commercially available craft materials (silicone, rubber) were tried and tested by the authors. The following materials (Table 1) were considered to provide the adequate feel of the ocular tissue being simulated.

Validation

Previously validated questionnaire design (ref. 12) was modified to assess face, content and utility of the strabismus model (Appendix 1). Questionnaires were distributed at a regional and international strabismus workshop to assess face, content validation and utility of the eye model. Whilst simulating horizontal muscle recession, we asked our participants (Speciality Trainee Year (ST) 3 – 7, Fellows and Consultants) to rate the following items using a five-point Likert scale; one being poor agreeability and five scoring highly favourable opinion.

Face validity measures the resemblance of the simulation to real life surgical procedure. We performed this by assessing the realism of the tissue simulated by the model, in particular focussing on conjunctiva, muscle, sclera and overall experience.

Content validity assesses a specific skill being developed during the simulation. This is in contrast to construct validation, which tests the ability of a simulation to distinguish between skill level e.g. novice versus expert. We surveyed our participants on their beliefs of how useful the model was in teaching specific aspects of strabismus surgery; muscle dissection, securing muscle, suturing muscle, developing hand eye co-ordination and maintaining hand-eye coordination.

We assessed utility of the model based on cost and experience, and its comparison with other dry and wet simulation models.

Statistical analysis was performed on SPSS version 23. A score of 3.3 for a given domain was considered to be adequate. Scores greater than 3.5 were considered favourable and less than 3.0 were considered inadequate, based on previous studies on face and content validation. (ref. 9). Analysis was performed using ANOVA One-way testing to seek statistical difference between defined subgroups ((Junior ST 3-4, Senior ST 5-7), Expert (Consultants and Fellows), International participants). Post-hoc Fisher's least significant difference was performed to ascertain which mean is statistically significant amongst the groups, taking account of multiple statistical testing.

Results

We had a total of 26 participants from the regional workshop across different grades: Junior Trainee (ST 3-4, n=8) average of 13.5 surgical strabismus cases performed (range 1-25), Senior Trainee (ST 5-7, n=15) average of 25.9 (range 17-30) and Expert (Consultant, n=3) with over 75 cases performed. In addition, we had 16 residents from the International workshop in Nairobi, Kenya with variable levels of training (ST1 – Consultant), performing an average 0.5 cases each.

Face Validity

Overall, our participants reported that the model replicated the eye accurately for training (mean 3.95, SD 0.70), in particular for simulated strabismus surgery (mean 3.93, SD 0.87). This was significantly reported higher in the expert group compared to junior or senior trainees ($p=0.02$).

Suturing and securing muscles felt realistic and both scored highly (mean 3.93, SD 0.68 and 3.86, SD 0.68 respectively). This was reported significantly higher in the expert group compared to junior or senior trainees ($p<0.01$). The feel of muscle dissection was considered to be adequately simulated (mean 3.24, SD 0.98). Significant difference was observed between the senior trainee and our international participants, with the latter group scoring higher ($p=0.023$).

With regards to the feel of the tissue, muscle and sclera felt realistic to our participants during practice (mean 3.36, SD 0.93 and 3.81, SD 0.71 respectively). No difference was observed between the groups for scleral feel ($p=0.28$). However, significant difference was observed between the senior trainee and our international participants with regards to feel of the muscle, with the international group rating the feel of muscle higher ($p<0.01$).

Conjunctiva was considered inadequate (mean 2.42, SD 0.97) with no difference observed amongst the groups ($p=0.36$).

Content Validity

Participants reported the model to be adequate for training in muscle identification (mean 3.31, SD 1.09). Moreover, the model was reported as more useful for practicing securing and suturing muscle (mean 4.29, SD 0.64 and 4.24, SD 0.66 respectively). No differences were observed between the user groups ($p=0.610$, $p=0.11$, $p=0.05$ respectively).

It was considered an excellent model for developing and maintaining skills in strabismus surgery (mean 4.29, SD 0.74 and mean 4.29, SD 0.83), with all participant groups rating these domains highly ($p=0.22$, $p=0.07$ respectively).

Utility

Respondents were favourable in recommending the model for training (mean 4.19, SD 0.67), particularly due to the low cost (mean 4.10, SD 0.91) and realism (mean 3.79, SD 0.89) offered. Realism was reported higher by the expert group compared to other participants ($p<0.01$).

24 out of the 42 participants have had prior experience with simulation models for strabismus surgery. Participants reported that our low-cost model was comparable with other dry models (mean 3.91, SD 0.67), and considered adequate compared to wet lab experiences (mean 3.32, SD 0.84). No significant differences were observed amongst the subgroups ($p=0.437$, $p=0.90$).

Discussion

Our model met the criteria for face and content validation. Current commercially available strabismus training models with refined materials are available (ref. 13) at a cost between £33 – 49 per eye. This is a substantial cost to training, as practice is limited to four recti muscles and/or two oblique muscles. In contrast, our self-developed model allows more practice by re-joining the recti onto the globe for a considerably lower cost (<£1-5). Furthermore, more experienced participants (senior trainees and consultants) reported that our low-cost model was comparable and favourable with other dry models they had used (mean 3.91), and felt it adequately compared to cadaveric high-fidelity simulation (mean 3.32). No significant differences were observed amongst the subgroups. Which is supportive of this model compared to other commercially available models.

Alterative descriptions of a low-cost model have been proposed, initially by Metz et al in 1980, whom described a simple model using tennis ball (globe) and rubber band (rectus muscle) (ref. 14). However, due to the density of the materials, Metz and colleagues advised practice of figure-of-eight sutures with 2-0 silk. This is an appreciably larger suture size than typically used in strabismus surgery where 6-0 vicryl is routinely employed. A recent modification by Adebayo and colleagues, demonstrated 6-0 polyglactin is also possible with alterative soft rubber band and ball model (ref. 15).

Adebayo et al, further performed construct validity by comparing single wet lab biological training to non-biological home training model and found comparable results at the end of a one-month training exercise (ref. 15). The demonstrated non-inferiority of non-biological wet lab training is further evidence that despite the limitation perceived, they can perform as well as expensive wet lab training without use of animal tissue and cost constraints. Furthermore, they offer a deliberate distributed form of practice compared to single high fidelity training, which has been shown to be more developmental towards learning (ref. 16).

The identified limitation of our model, replication of conjunctiva and feel of muscle dissection, is not unique to our model but can be applied to all non-biological models. Biological tissue planes and structures are difficult to replicate due to the level of hydration, thickness and variations in anatomy.

The muscles were easily identified and therefore did not pose a challenge, when compared to biological models in which muscle-tenon fibre separation can prove far more difficult. White et al, evaluated composite simulated model using bacon acquired from local supermarket to simulate extra-ocular muscle surgery. This was found to be constructive to learning as the biological tissue offered a realistic approach to extra-ocular muscle tissue dynamics (ref. 12) with a relatively inexpensive cost. However, the Styrofoam base was a less favourable scleral substitute. Using composite biological tissue (e.g. bacon, chicken skin for conjunctiva) may therefore overcome some of the issues with non-biological materials, however, this requires further evaluation.

Generally, there was an agreement between our participants in their rating for each domain of validity. However, a significant difference was observed between our senior trainee and international participant group for muscle dissection and feel of muscle despite the similar sample size in each group. The latter group had less experience in strabismus surgery and simulation and was composed of participants with a wider training disparity, which may have contributed to a higher perceived rating. Nonetheless, no difference was found when compared to the junior or expert groups to suggest this observation may represent a normal distribution.

Furthermore, our expert group scored overall simulation, anatomy and feel of muscle securing and suturing significantly higher than all our other participants. This is perhaps due to the validity and applicability of the model to basic skills required in strabismus surgery from experience of surgery and training. Further sampling of experts is desirable to ascertain the likelihood of this effect but is difficult to assess in a single ophthalmic unit.

Conclusion

Our proposed low-cost accessible strabismus model scored well for face and content validation. In particular, the model scored highly for muscle securing and suturing which we believe are the most challenging aspects of the surgical learning curve. The muscle dissection and conjunctival simulation was considered less realistic. Overall, participants felt that the model simulated horizontal muscle surgery well and was comparable to other dry simulation models.

Conflict of Interest
There are no direct benefits to the research participants or study authors.

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Titles and Legends to Figures

Table Legends

Table 1. Material requirement for low cost strabismus model

Figure Legends

Figure 1. Low Cost Strabismus Model. Full guide on making the model can be found on the following link: https://www.youtube.com/watch?v=PHGZnPZDdEY or by searching “Jain Eye model” on Youtube.

Figure 2. Distribution of rating by surgeon grade of the defined domains for face validity

Figure 3. Distribution of rating by surgeon grade of the defined domains for content validity