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Reverse order method for teaching cataract surgery to residents

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ABSTRACT

Objective To implement a method to train residents in the performance of phacoemulsification surgery, with the steps completed in reverse chronological order and with the easiest step being undertaken first.

Methods and analysis We created a method for training ophthalmology residents in which we taught phacoemulsification surgery in a series of steps learnt in reverse order. Each resident advanced through the teaching modules only after being approved in the final step and then progressed to the complete performance of surgeries. We analysed the rates of complications in the 2 years after introducing the new method.

Results The new method allowed for a standardised approach that enabled replicated teaching of phacoemulsification regardless of instructor or student. After implementing the new method, residents performed 1817 phacoemulsification surgeries in the first year and 1860 in the second year, with posterior capsule rupture rates of 8.42% and 7.9%, respectively.

Conclusions Teaching residents to perform the steps of phacoemulsification in a standardised reverse order resulted in low rates of complications.

Key messages

What is already known about this subject?

- Cataract surgery presents several challenges regarding the learning process, resulting in varying complication rates.

What are the new findings?

- A standardised approach towards cataract teaching may reduce complication rates among beginning resident surgeons.

How might these results change the focus of research or clinical practice?

- A system of checkpoints and logbooks allows for replication of this teaching method in other teaching facilities and clinical practices.

INTRODUCTION

Cataract constitutes 51% of the 39 million cases of blindness per year worldwide.[1] The only effective treatment is surgery, involving removal of the opaque lens and replacement with an artificial intraocular lens (IOL),[2–5] to re-establish the transparency of the media and promote improved visual acuity.[1 5 6] The WHO set a goal in 2011 of reducing avoidable causes of blindness, among which cataract is the main curable cause,[1 7] by 25% by 2019.[3] In well-organised and well-equipped facilities, a single surgeon can perform 1000–2000 surgeries yearly,[1] so the training of new surgeons in this technique is essential.

Training for phacoemulsification is 'step-dependent',[8 9] that is, acquiring surgical skill depends on the mastery of previous steps. However, the training method for this technique has traditionally been based on teaching young physicians the surgical steps in the temporal order applied during real surgery; that is, from the first to the last step.[9]

The complication rate of phacoemulsification surgery decreases with the learning curve; two studies reported a reduction of 50% after a few dozen surgeries had been performed,[10 11] while another reported a similar reduction after hundreds of surgeries.[12] Acquiring proficiency is challenging because surgery involves people in need of treatment who require safe procedures.[12] Thus, complications must always be considered when incorporating new pedagogical techniques in a training centre.

The complication rate of ultrasonic phacoemulsification surgery varies among reports.[11–13] This may be due to intrinsic factors, such as differences in patient age and comorbidities,[14] the technique used and the level of experience of the surgeon or resident. This, in turn, affects the duration of surgery, which should decrease with the learning curve.[13 15] The posterior capsule rupture (PCR) rate in phacoemulsification can reach 14.7%[16] when performed by trainees and can remain high even when performed by experienced surgeons.[17]

The purpose of this study was to investigate the complication rate of a new method of training residents in phacoemulsification based not on the order in which the steps are performed during surgery, but rather on the difficulty of each step. In this manner, the final

step of the surgery (ie, the step that is the least dependent on the steps, and thus also the easiest) is taught first. The other steps are subsequently taught in reverse order until the resident has learnt and can perform the entire surgery.

METHODS

Study design and ethics

This was an observational study in which we evaluated the outcomes of an educational intervention on ophthalmology residents. Participants were second-year and third-year residents in a university hospital providing free services to the general population.

Participants

The participants in this study were second-year and third-year residents in ophthalmology (R2 and R3). During both years of the study period, the number of residents in training was the same: 12 R2 and 12 R3 in the first year, and 12 R2 and 12 R3 in the second year. All residents participated in the study. R3 residents in the first year of the study had been trained previously using the same method of this study. Within the unit, there were two surgical preceptors in each study year; the volume of operations of this type was approximately 2000 surgeries per year. All preceptors adhered to the study protocol during the study period and trained the second-year residents according to the methods described herein.

We evaluated all patients referred to the surgical centre with an indication for phacoemulsification surgery in terms of their suitability for inclusion in the study. On the scheduled day of surgery, the preceptor evaluated the patient to confirm the surgical treatment indication and that they were in suitable condition for surgery. We included only patients with good mydriasis (>6 mm), a transparent cornea, a lens with cataract and an intermediate nuclear opacity intensity of 2 on a rating scale ranging from 1 to 4, or a potentially related posterior subcapsular opacity.[15]

We excluded patients with ophthalmic comorbidities (ie, pseudoexfoliation syndrome, zonular laxity and shallow anterior chamber (<2 mm)) and those whose clinical condition had certain characteristics that could have made the surgical procedures more difficult (ie, obstructive pulmonary disease, neurological disorders, spinal disorders and morbid obesity). In such cases, experienced surgeons conducted the surgery, and the patients were not entered into the residents' surgical records.

Patients and public involvement

Patients were not directly involved in the recruitment or conduct of this study. Data obtained from this study were made available on direct request to the corresponding author.

Phacoemulsification teaching methods

We adopted the 'stop and chop' technique[18] which includes all of the fundamental elements of phacoemulsification surgery, such as sculpting a central sulcus, performing fracture of the two heminuclei, applying chopping techniques in the heminucleus and emulsification of the quadrants. Thus, after the minimum number of surgeries, the student was able to perform the main phacoemulsification steps.

We used the following parameters throughout the study: for central sulcus sculpturing, we set the vacuum at 80 mm Hg and aspiration at 25 mL/min, and used a continuous ultrasonic energy of 60%. All cases used the Infiniti phacoemulsification system (Alcon Labs, Fort Worth, California, USA). For chopping, emulsification and aspiration of the lens quadrants, we set the vacuum at 250 mm Hg and aspiration at 40 mL/min, and used a pulsed ultrasonic energy of 60%. All cases were performed under peribulbar anaesthesia.

Since phacoemulsification surgery is step-dependent, we created a method structured according to the degree of difficulty of the steps. The residents began by learning the less step-dependent procedures, and progressed to the next step only after the instructor had approved their performance during the previous one; evaluation checkpoints were used. Approval was obtained subjectively by the instructor based on manual dexterity, identification of ocular structures (ie, anterior capsule, corneal endothelium, lens quadrants and cortex) and time to perform the procedure. We established that residents should perform at least four surgeries before progressing to the next checkpoint (total of 20 surgeries).

We created a logbook, based on that of the Royal College of Anaesthetists,[19] detailing the progress of each resident in terms of the evaluation checkpoints. A signature in the logbook from the preceptor was mandatory for progression. After each surgery, the resident pasted the patient's tag (containing their name, registry number and surgery) into the logbook.

Chronological sequence of the surgery and teaching sequence

We broke down the stop and chop technique into a chronological sequence of 10 steps. Adherence to this sequence was mandatory for both instructors and residents. Steps 1–10 denote the order of procedures during actual surgery, but for the purposes of teaching, this order was reversed; thus, the resident began training by watching the complete surgery, but initially, he/she performed only steps 7, 9 and 10 without assistance. Within this system of progressive difficulty, the resident could proceed to the next step only after mastering the previous ones. The sequence of the phacoemulsification steps is presented below.

Surgical steps

1. Incisions
   1.1. Paracentesis, 15°
   1.2. Limbic corneal incision, 2.75 mm
2. Ophthalmic viscosurgical device (OVD) injection
3. Capsulorhexis

3.1. Opening
3.2. Intermediate capsulorhexis
3.3. Finalisation
4. Hydrodissection and hydrodelineation
5. Nucleus 'stop and chop'
5.1. Sulcus
5.1.1. Sculpturing of half of the sulcus
5.1.2. Nucleus rotation
5.1.3. Finishing the sulcus sculpture
5.2. Fractures
5.2.1. Sulcus fracture
5.2.2. Fracture (chop) of the first heminucleus
5.2.3. Fracture (chop) of the second heminucleus
5.3. Emulsification
5.3.1. Emulsification of the first quadrant
5.3.2. Emulsification of the second quadrant
5.3.3. Emulsification of the third quadrant
5.3.4. Emulsification of the last quadrant and epinucleus
6. Irrigation and aspiration of cortical remnants
7. Injection of OVD into the capsular bag and anterior chamber
8. Insertion of IOL
9. OVD aspiration
10. Suture with nylon, 10.0

Checkpoints

We established checkpoints at which learning could be evaluated to check on the progress of the residents and to decide whether more responsibilities should be allocated. At each checkpoint, the instructor assessed the residents' ability to perform a procedure without assistance.

Checkpoint 1

Instructor: Steps 1–6 and 8
Resident: Steps 7, 9 and 10 (OVD injection and aspiration, suture and no IOL implantation)

Checkpoint 2

Instructor: Steps 1–3.2 (intermediate capsulorhexis)
Resident: Step 3.3
Instructor: Steps 4–5.3.1 (emulsification of quadrant 1)
Resident: Steps 5.3.2 and 5.3.3 (quadrants 2 and 3)
Instructor: Step 5.3.4 (quadrant 4 and epinucleus)
Resident: Steps 6–10

Checkpoint 3

Instructor: Steps 1–3.1 (initial capsulorhexis)
Resident: Steps 3.2 and 3.3
Instructor: Step 4
Resident: Steps 5.1–5.2.1 (sulcus fracture)
Instructor: Step 5.2.2 (chop of heminucleus 1)
Resident: Steps 5.2.3–5.3.3 (quadrant 3)
Instructor: Step 5.3.4 (quadrant 4 and epinucleus)
Resident: Steps 6–10

Checkpoint 4

Instructor: Steps 1–3.1 (initial capsulorhexis)
Resident: Steps 3.2 and 3.3
Resident: Steps 4–5.3.3 (quadrant 3)
Instructor: Step 5.3.4 (quadrant 4 and epinucleus)
Resident: Steps 6–10

Checkpoint 5

Instructor: Intersperse 1.1, 1.2 and 2 with the resident
Resident: Steps 3–10

Outcomes and variables

We collected data from logbooks and medical records to assess complications (frequency and type) during and after surgery. The main outcomes were the absolute and relative rates of PCR during the phacoemulsification surgeries performed by the residents (individually and at the group level). Secondary outcomes included anterior capsule rupture (ACR), IOL rupture, zonular rupture or dialysis, iris injury (IRI), Descemet's membrane detachment and fragmentation of the nucleus in the vitreous cavity.

Statistical analysis

We present the data descriptively, as rates and averages. We compared the PCR rates among the years using the χ^2 test. We estimated ORs of the PCR rates and CIs using a generalised linear model with binomial distribution. We set the level of significance at $p<0.05$ and used SPSS V.18.0 for Windows statistical software for the analyses.

RESULTS

A total of 3677 procedures were included in this study. In the first year after adopting the new method (year 1), 1817 (49.4%) phacoemulsification surgeries were performed. In the second year (year 2), 1860 (50.6%) procedures were performed. Table 1 presents that PCR was the most frequent complication. Other complications included ACR, IOL damage, zonular dialysis, IRI, Descemet's detachment and nuclear fragments in the vitreous chamber. However, these complications affected <3% of all cases. The total numbers of PCR events were 153 in year 1 and 147 in year 2. The rate of PCR complications was not significantly different in years 1 and 2 of the study, with an OR of 0.37 and 0.35, respectively (table 2).

DISCUSSION

In this study, we obtained good clinical results using a new training method for cataract surgery designed for residents. This new method features well-defined steps that are performed in the reverse order to that of actual surgery, such that residents learn the easiest step first. We believe that any educational programme for surgery should follow a systematic methodology that is reproducible and can be compared with other methods in terms of clinical results,[8] with the aim of standardising the teaching procedure. The current method should be easily reproducible. The clinical outcomes obtained with this method were comparable

Table 1 Absolute and relative rates of complications of phacoemulsification surgeries performed by second-year and third-year residents

		PCR		ACR		IOLB		ZR		IL		DMD		VCF	
Year/month	n	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Year 1															
January	123	8	6.5	2	1.6	0	0	2	1.6	2	1.6	1	0.8	0	0
February	148	14	9.5	1	0.7	0	0	1	0.7	1	0.7	0	0	0	0
March	174	15	8.6	2	1.1	2	1.1	0	0	1	0.6	0	0	0	0
April	170	17	10	2	1.2	3	1.8	0	0	1	0.6	1	0.6	2	1.2
May	119	11	9.2	1	0.8	1	0.8	1	0.8	1	0.8	2	1.7	1	0.8
June	122	12	9.8	3	2.5	2	1.6	2	1.6	1	0.8	1	0.8	0	0
July	168	9	5.4	3	1.8	1	0.6	0	0	3	1.8	0	0	2	1.2
August	179	15	8.4	4	2.2	3	1.7	0	0	1	0.6	0	0	1	0.6
September	151	14	9.3	2	1.3	4	2.6	1	0.7	1	0.7	0	0	1	0.7
October	170	14	8.2	1	0.6	1	0.6	1	0.6	1	0.6	1	0.6	2	1.2
November	149	13	8.7	2	1.3	1	0.7	0	0	1	0.7	2	1.3	1	0.7
December	144	11	7.6	1	0.7	0	0	2	1.4	2	1.4	1	0.7	1	0.7
Total	1817	153	8.4	24	1.3	18	1	10	0.6	16	0.9	9	0.5	11	0.6
Average	151														
Year 2															
January	142	11	7.7	0	0	1	0.7	0	0	2	1.4	0	0	0	0
February	135	12	8.9	3	2.2	0	0	1	0.7	2	1.5	1	0.7	2	1.5
March	159	16	10.1	3	1.9	0	0	2	1.3	1	0.6	1	0.6	1	0.6
April	137	12	8.8	4	2.9	2	1.5	2	1.5	1	0.7	0	0	1	0.7
May	143	11	7.7	1	0.7	3	2.1	1	0.7	1	0.7	0	0	1	0.7
June	155	16	10.3	0	0	2	1.3	0	0	0	0	1	0.6	2	1.3
July	182	9	4.9	0	0	0	0	0	0	3	1.6	0	0	1	0.5
August	173	13	7.5	2	1.2	4	2.3	1	0.6	3	1.7	0	0	3	1.7
September	180	11	6.1	1	0.6	1	0.6	1	0.6	3	1.7	0	0	1	0.6
October	152	12	7.9	1	0.7	0	0	1	0.7	0	0	0	0	0	0
November	164	13	7.9	0	0	0	0	0	0	0	0	0	0	0	0
December	138	11	8	0	0	2	1.4	0	0	0	0	1	0.7	1	0.7
Total	1860	147	7.9	15	0.8	15	0.8	9	0.5	16	0.9	4	0.2	13	0.7
Average	155														

ACR, anterior capsule rupture; DMD, Descemet's membrane detachment; IL, iris lesion; IOLB, intraocular lens breakage; PCR, posterior capsule rupture; VCF, core fragment in the vitreous cavity; ZR, rupture of the zonula.

to those reported internationally, and superior to those recorded previously in our hospital.[20]

In our study, we excluded patients with comorbidities. These patients might have acted as confounders in the analyses of complications. We are aware that this might present a risk of bias since patients without comorbidities tend to have fewer complications; however, this ensures better homogeneity of the sample. Patients with comorbidities were also excluded in a study by Carricondo.[13]

Moreover, we excluded complex patients because previous studies failed to report the criteria used for selecting patients who could be operated on by residents. The complication rates of phacoemulsification surgeries performed by residents are high.[12 16 21 22] In one study,[16] the majority of cases of vitreous loss occurred in situations in which the technical difficulty of the surgery could be predicted, or in eyes with a small pupil or a nuclear sclerosis grade of 4+; this emphasises the importance of patient selection for surgical training.

Table 2 Generalised linear model with a binomial distribution of the posterior capsule rupture (PCR) rate in cataract surgeries performed in years 1 and 2 after introducing a new training programme

	PCR, n (%)			95% CI	
Year	No	Yes	OR	Inferior	Superior
1	1664 (91.6)	153 (8.4)	0.37	0.28	0.50
2	1713 (92.1)	147 (7.9)	0.35	0.26	0.47
Total	**3377 (91.8)**	**300 (8.2%)**			

Evaluation checkpoints are an important component of our training method. The learning curve of a surgical technique sometimes entails the performance of a large number of actual surgeries. However, during the learning curve period, patients may be at higher risk of suffering complications. By requiring the students to pass through the five checkpoints four times, the educational objectives could be met after fewer surgeries. Therefore, surgeries were considered to be performed independently after the twentieth procedure. In this study, the students learnt faster and the complication rates were comparable to previous reports in the literature.[13 23–27]

By the end of the 1990s, the overall complication rates of surgeries performed by residents have decreased.[12 28–30] In seven studies published at that time, the rate of PCR among resident-performed surgeries was 2%–10%, while the vitreous loss rate ranged from 1.8% to 10.4%.[23–27] In 2010, Carricondo[13], in Brazil, reported PCR rates of 11.49% for uncomplicated cataracts. Subsequent studies[28 29 31–33] reduced these rates even further (2%–5%), although bias was present and it was unclear which complications were included in each analysis. These large variations in reportage must be reduced to allow comparison of complication rates among studies. National electronic data sets, such as used by the Royal College of Ophthalmologists,[19] have allowed for closer monitoring of complications. PCR rates for less experienced trainees were as low as 2.3%.[30] We chose to ascribe greater importance to PCR in our study because it was the most frequently encountered complication and directly affects the visual prognosis.[28] In a recently published study,[34] a reverse order teaching method was also assessed. However, although the rate of PCR was lower after the implementation of the educational programme, the difference was not significant. This may have been due to the small sample size; that study involved 32 surgeons and 609 patients.

Teaching surgery in a step-by-step manner requires detailed records of each student's improvement.[9] At our institution, prior to the implementation of the new teaching method, patient medical records were irregular and there was no standardised method for documenting complications (except for PCR); this led to heterogeneous information regarding the various complications. Furthermore, there was no facility for recording difficulties, that is, the steps that students found most difficult to master. Hence, there was a clear need to develop and systematise a logbook system. In a preliminary review of charts before the implementation of this new method, a PCR rate of 19.89% was detected among R2 and R3 procedures.[20] This data, while used as a benchmark for our study, was not included in the study due to statistical and methodological bias. The high rate of complications present in the service did not allow for the comparison of previous and current teaching methods.

We based our logbook on that of the Royal College of Anaesthetists.[19] In this individual record book, checkpoints were used to monitor the progress of the residents. Other fields were used to describe complications and any challenging aspects of the surgery. A resident could move on to the next checkpoint only after approval and with the signature of the supervising surgical preceptor. Thus, the requirement for a signature from the preceptor forced the student to perform all of the required steps and surgeries. This enabled us to obtain more reliable data on complication rates, and also allowed us to implement a teaching method that could be reproduced regardless of student or teaching staff. By standardising the patients, techniques and participating residents (in terms of their proficiency), it should be possible to compare our results with those of future studies.

This study presents limitations that are inherent to observational series. First, the lack of adequate chart data previous to the implementation of this method did not allow for statistical comparison with other teaching methods. Second, complications were registered as occurrences; however, the stage of complication was not registered, this could further help better orientation regarding critical surgical steps. Third, clinical data, such as surgical time, endothelial cell count and corneal central thickness, are not registered, at our service, in routine cases that are used for surgical teaching. Further studies should address these issues, as well as evaluate the implementation of this method for other surgical techniques or evaluation of the learning curve within different stages of learning.

Most studies in the literature focus on the data produced by surgeons in training or residents, not on the training itself. To the best of our knowledge, a fully standardised teaching procedure has not yet been previously reported. This technique should allow for adequate evaluation of residents' technique within services or across different locations. This should also allow for evaluation of different stages during learning curves.

This study showed that instructing residents in the steps necessary for phacoemulsification in reverse chronological order presents low intraoperative complication rates. The creation of a logbook system was useful for instilling the discipline required for progression through the steps, and the logbook also served as a reference tool for evaluating the progress of individual students. Further reduction of residents' phacoemulsification complication rates over time should be the goal of future studies.

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Contributors GRM was responsible for concept and design, data acquisition and analysis, manuscript drafting, overall content and final approval of the manuscript. JCL was responsible for concept and design, manuscript revision and final approval of the manuscript. ESS was responsible for concept and design, manuscript critical revision and final approval of the manuscript. WN was responsible for concept and design, manuscript supervision and final approval of the manuscript.

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