Step-by-step phacoemulsification training program for ophthalmology residents

Wang Yulan, Sheng Yaohua, Tao Jinhua, Wang Min

Aims: The aim was to analyze the learning curve of phacoemulsification (phaco) performed by residents without experience in performing extra-capsular cataract extraction (ECCE) in a step-by-step training program (SBSTP). Materials and Methods: Consecutive surgical records of phaco performed from March 2009 to Sept 2011 by four residents without previous ECCE experience were retrospectively reviewed. The completion rate of the first 30 procedures by each resident was calculated. The main intraoperative phaco parameter records for the first 30 surgeries by each resident were compared with those for their last 30 surgeries. Intraoperative complications in the residents’ procedures were also recorded and analyzed.

Results: A total of 1013 surgeries were performed by residents. The completion rate for the first 30 phaco procedures was 79.2 ± 5.8%. The main reasons for halting the procedure were as follows: Anterior capsule tear, inability to crack the nucleus, and posterior capsular rupture during phaco or cortex removal. Cumulative dissipated energy of phaco power used during the surgeries was significantly less in the last 30 cases compared with the first 30 cases (30.10 ± 17.58 vs. 55.41 ± 37.59, P = 0.021). Posterior capsular rupture rate was 2.5 ± 1.2% in total (10.8 ± 4.2% in the first 30 cases and 1.7 ± 1.9% in the last 30 cases, P = 0.008; a statistically significant difference). Conclusion: The step-by-step training program might be a necessary process for a resident to transit from dependence to a self-supported operator. It is also an essential middle step between wet lab training to performing the entire phaco procedure on the patient both effectively and safely.

Key words: Complication, phacoemulsification learning curve, resident training

Traditional phaco training programs include studying basic literature on phacoemulsification, wet lab practice, performing 10-20 extra-capsular cataract extractions (ECCE), and starting phacoemulsification under supervision. Phacoemulsification is currently the most preferred technique for cataract surgery; ECCE may not be appropriate to perform merely for training purposes. Some trainers fear that moving directly to resident-performed phacoemulsification would lead to higher complication rates. Posterior capsule rupture with or without vitreous loss is the main undesirable intraoperative complication of phaco surgery. The incidence of vitreous loss during ECCE by residents was reported to be about 2.4-9%, while in phacoemulsification, it ranged from 1.8% to 10%.

We would like to train residents who had no ECCE experience to perform phacoemulsification safely and quickly. Herein, we established a step-by-step training program (SBSTP) and followed each resident included in this program to observe their learning curve and thereby evaluate training effectiveness.

Materials and Methods

Surgical records of consecutive phacoemulsifications performed by four residents without any previous ECCE experience from March 2009 to September 2011 were retrospectively analyzed. All residents were followed as per a schedule prepared in our SBSTP design. The primary evaluation criteria included the following: Completion rate of the first 30 procedures, phaco time, and percentage phaco power used in the operation. The completion rate was defined as the frequency of surgeries completed independently by the residents. Main intraoperative phaco parameter records for the first 30 surgeries performed by each resident were compared with those for their last 30 surgeries. If a supervisor took the position of primary surgeon for any step, it was scored as an incomplete case. For completion rate and associated complications analysis, incomplete cases were computed, but in energy comparison analysis, they were excluded.

Training program

Residents included in the SBSTP adhered to the following training sequence: Acting as a scrub-on phaco assistant for 300 cases, studying basic literature on phacoemulsification and passing an exam, and practicing basic surgical steps in a wet lab on 50 porcine eyes. Next, candidates entered the step-by-step skill practice on patient eyes. In this stage, we asked the residents to practice steps progressively in the following sequence: Step 1, intraocular lens (IOL) implantation; step 2, incision construction; step 3, cortex removal; step 4, continuous curvilinear capsulorhexis; and step 5, nucleus fragment emulsification. Upon finishing the first step for 30 cases without any associated complications, the resident would be allowed to move to the next, more complicated step. After finishing all five steps, the residents started performing the complete phacoemulsification procedure independently and under supervision.
The completion rate of the first 30 independently performed phaco cases was recorded for each resident. Cumulative dissipated energy (CDE) for each case was recorded. All phaco procedures were done using the Infiniti phaco machine (Alcon Surgical). Ozil Intelligent Phaco (IP) torsional mode was recommended to be used. Since most nucleus density in teaching cases were classified to grades 2 and 3, our usual training settings for sculpting was 60-80% linear torsional (Ozil IP off), 120 mmHg linear vacuum, and 90 cm bottle height; for quadrant removal is 80% linear torsional (Ozil IP on), 320 mmHg fixed vacuum, and 95 cm bottle height; for irrigation aspiration (I/A) is 500 mmHg linear vacuum, 80 cm bottle height.

The phaco procedures in SBSTP were supervised by two attending surgeons (Y.S. and Y.W.) according to the standard phaco processes: Superior 2.8 mm clear corneal incision constructed, flap performed using a bent 25-gauge needle and continuous circular capsulorhexis completed with the capsule forceps, hydrodissection in multiple directions, stop-chop or divide and conquer technique used to deal with a central nucleus, injection of a foldable intraocular lens after complete cortex removal, and securing the incision with a 10-0 nylon suture, if necessary. Supervisors had the priority to stop a resident’s phaco attempt in situations such as anterior capsular runaway, inability to complete continuous curvilinear capsulorhexis (CCC), failure to separate the nucleus after three trials, any dangerous movement in the eye, difficulty keeping a stable anterior chamber depth during any step, and the occurrence of intraoperative complications. A discussion meeting using surgical videos was arranged weekly.

Data evaluation
Data were listed and counted with Excel (version 2007, Microsoft). The Fisher exact, Chi-square, and Student t-tests were used to assess statistical significance between groups.

Results
All four residents finished five-step training within 6 months. For each step, at least 30 cases without any associated complications were performed.

When residents entered the stage of performing complete phacoemulsification on patient eyes as a primary surgeon, the first 30 consecutive cases were recorded and scored by a supervisor. Table 1 shows the completion rate for the first 30 phaco cases of each resident and lists the main problems in incomplete procedures.

At the end of observation time, 1013 phacoemulsification procedures were independently performed by residents. The mean patient age was 73.2 ± 16.5 years (standard deviation; SD). The male/female ratio was 0.87. Each resident performed a mean of 253 phaco procedures. Table 2 shows the main intraoperative phaco parameters for the first 30 surgeries performed by each resident compared with their last 30 surgeries. Cumulative dissipated energy of phaco power used during the surgeries was statistically significantly less in the last 30 procedures compared to that in the first 30 procedures (30.10 ± 17.58 vs. 55.41 ± 37.59, t = 2.457, P = 0.021), accompanied by a statistically significantly decrease of mean phaco time (P = 0.032).

Main intraoperative complications are listed in Table 3. The total posterior capsular rupture (PCR) rate was 2.5 ± 1.2%. In the first 30 cases, the residents’ mean PCR rate was 10.8 ± 4.2%, which was statistically significantly higher than that in the last 30 cases (1.7 ± 1.9%; χ² = 99.23, P = 0.008). No nucleus dropping into the posterior segment occurred in those cases, but dropping of small epinucleus fragments occurred in three cases. Topical corticosteroids were given for 1.5 months. Regional zonular dialysis occurred in 4 cases, which all happened in small size capsulorhexis. All these cases had three-piece-foldable IOL inserted into the bag, and 2 cases involved insertion of additional capsular tension ring for support. No further posterior segment complications were observed at the end of the follow-up period.

Discussion
China will soon have the world’s most rapidly aging population and the largest unoperated cataract subject pool. However, the surgical cataract rate (CSR) in this country is only 450/ per million, compared to 5000-6000/per million in developed countries. One key solution to accommodate this situation is to enhance the efficiency and safety in current phaco training programs to cultivate better qualified cataract surgeons.

Acting as a scrubbing assistant for more than several hundred cases, studying recent literature on phacoemulsification, and skill-training in wet labs are common requests in resident training programs. These offer candidates the basic skills and knowledge to assist surgeons operating on patient eyes using a phaco machine. With these techniques, trainees, as scrubbing observers, are able to collect useful ideas pertaining to basic phaco processes, risk evaluation, and recognition of early signs of complications and their management. The more written information pertaining to phacoemulsification that is learned, the quicker an assistant can understand operators’ standards and individual behavior in the operating room. Usually, a surgeon is more receptive to allowing an assistant to perform

| Completion of phacoemulsification procedures performed by each resident | Completion eyes, n (%) | Anterior capsule tear eyes, n (%) | Nucleus cracking difficulty without PCR eyes, n (%) | Nucleus cracking difficulty with PCR eyes, n (%) | PCR while dealing with nucleus fragments eyes, n (%) | PCR during IA eyes, n (%) |
|------------------------------------------------|------------------------|-------------------------------|------------------------------------------|------------------------------------------|------------------------------------------|------------------------|
| A                                             | 26 (86.7)              | 2 (6.7)                       | 1 (3.3)                                  | 1 (3.3)                                  | 1 (3.3)                                  | 1 (3.3)                |
| B                                             | 23 (76.7)              | 2 (6.7)                       | 1 (3.3)                                  | 1 (3.3)                                  | 2 (6.7)                                  | 1 (3.3)                |
| C                                             | 23 (76.3)              | 3 (10)                        | 2 (6.7)                                  | 1 (3.3)                                  | 1 (3.3)                                  | 1 (3.3)                |
| D                                             | 23 (76.7)              | 3 (10)                        | 1 (3.3)                                  | 1 (3.3)                                  | 3 (2.5)                                  | 2 (6.7)                |
| Average                                       | 95 (79.2)              | 10 (8.3)                      | 2 (1.7)                                  | 5 (4.2)                                  | 3 (2.5)                                  | 5 (4.2)                |

PCR: Posterior capsular rupture, IA: Irrigation aspiration
some simple steps of the procedure, such as suturing incision and insertion of an IOL, if the assistant shows stable hands under a surgical microscope after persistent practice on porcine eyes.\[6,7\]

After training as a scrubbing assistant for a period of time, a trainee moves to a partial surgeon capacity and only performs assigned steps. In this stage, a candidate has many opportunities to progressively optimize the assigned step under supervision. If a chief surgeon believes that the trainee is free from errors in this step, the trainee is allowed to move on to the next step of the training program. The difficult steps for residents included nucleus disassembly and removal, cortex removal and capsulorhexis, while IOL insertion and incision construction were easy.\[8-10\] Repetitive training of relatively simple steps is a key advantage of SBSTP. During this period, most trainees receive positive feedback with success and thereby enhance self-confidence in learning phaco techniques. Meanwhile, trainees can easily evaluate a candidate’s performance and develop a more realistic, individualized training schedule. Upon reaching the last several steps of phaco procedures, a trainee is already well trained in mastering manipulation in a limited space, bimanual cooperation, and fine 2-position-foot-pedal control and is ready to move to the step of dealing with the nucleus, which requires 3-position-foot-pedal control. All the benefits of this SBSTP enhance patient safety.\[11,12\]

Experience in ECCE does offer some benefits for improving basic surgical behavior in phaco procedures performed by trainees. Nowadays most surgeons no longer use ECCE to deal with routine cataract cases. Wound construction, capsulorhexis, and wound closure of ECCE were modified to accommodate current phaco procedures. Machine-dependent nucleus separation and fragmentation are completely different from the nucleus delivery technique in ECCE. Therefore, even a well-experienced ECCE surgeon might still have great difficulty transitioning into qualified phaco surgeon. The step-by-step training program might be also helpful for training the aforementioned surgeons. Some trainers worried about complication rate could be higher in phacoemulsification than in manual cataract surgery teaching. The main reason was that trainees lacking previous ECCE training have less experience performing capsulorhexis, which was one of the most difficult steps.\[2,13\] That might also support SBSTP to be a safe and helpful method to solve such problems. The report showed that intraoperative complication rates were comparably low for surgeons experienced with both phacoemulsification and manual cataract surgery technique.\[12\] Residents without ECCE experience could manage phacoemulsification after a suitable training program, but the alternative method of cataract removal skill also needs to be transmitted to them in future if possible. By our observation, most residents can manage the ECCE procedure easily and quickly even with limited cases after they have received adequate phaco experience. Managing phaco is a great progress for residents, but the alternative technique is always a precious essential backup skill for each mature surgeon.

In the current resident training programs in most countries, including China, the trainees have a very limited number of training procedures. Most residents feel that performing their first 30 phaco procedures is a great challenge; the resident usually fails either in the capsulorhexis step or the nucleus dealing step, and the majority of trainees are unable to perform the entire procedure independently.\[8,10\] Supervisors are also not daring enough to idly watch a trainee-performed surgery, which is full of risks. Teaching cases are usually accompanied with a prolonged surgical time. Teaching cataract surgery with a high degree of patient safety is always challenging. Thus, the actual number of surgeries performed solely by residents is extremely low.

A step-by-step training program helps residents become more familiar with foot pedal positions and allows them to become more experienced with machine control. Posterior capsular rupture is still the most prevalent intraoperative complication in phaco training; however, after our SBSTP, the mean PCR rate was 2.5% (25/1013), which was lower than other reports.\[2,3,13\] Especially in the beginning stage of phaco learning.

### Table 2: Phacoemulsification performance in the first 30 procedures and the last 30 procedures performed by each resident

| Parameter                        | First 30 procedures | Last 30 procedures | Mean phaco power (%) | Cumulative dissipated energy |
|----------------------------------|---------------------|--------------------|----------------------|-------------------------------|
| Phaco time (min)                 | 2.41±1.28           | 1.49±0.84          | 21.72±3.92           | 30.16±5.93                   |
| Mean phaco power (%)             | 21.72±3.92          | 20.36±5.93         | 55.41±37.59          | 30.10±17.58                  |
| Cumulative dissipated energy     | 55.41±37.59         | 30.10±17.58        | 55.41±37.59          | 30.10±17.58                  |

\*P<0.05

### Table 3: Main intraoperative complications following phaco performed by residents

| Complications                  | Corneal burn eyes, n (%) | Iris damage eyes, n (%) | Regional zonular dialysis eyes, n (%) | Posterior capsule rupture eyes, n (%) | Vitreous loss eyes, n (%) | Epinuclear fragments in vitreous eyes, n (%) |
|-------------------------------|--------------------------|-------------------------|---------------------------------------|--------------------------------------|--------------------------|---------------------------------------------|
| All 1013 procedures           | 10 (1.0)                 | 7 (0.7)                 | 4 (0.4)                               | 25 (2.5)                             | 19 (1.9)                 | 3 (0.3)                                     |
| First 30 procedures (120 total)| 4 (3.3)                  | 5 (4.2)                 | 3 (2.5)                               | 13 (10.8)                            | 10 (8.3)                 | 2 (1.7)                                     |
| Last 30 procedures (120 total)| 1 (0.8)                  | 0                       | 0                                     | 2 (1.7)                              | 1 (0.8)                  | 0                                           |
| \(\chi^2\)                    | 0.82                     | 0.006                   | 0.247                                 | 7.11                                 | 0.008*                   | 0.498                                       |
| \(P\)                         | 0.37                     | 0.060                   | 0.247                                 | 0.014                                | 0.498                    |                                             |

\*P<0.05
curve, our complication rate was lower than 12-19% by other reports. From previous resident training experiences, we found that PCR during phaco might relate to multiple factors, but PCR during I/A is mostly related to the ability to control the foot pedal. Virtual surgery simulator was reported to be helpful to develop the 2-hand and 2-foot coordination required during cataract surgery, which could improve operative performance and decrease complication rates in resident phacoemulsification cases. But the system might not be popularly used in most developing countries. Therefore, we selected the I/A cortex removal step as an important isolated training step, which was well received by residents. All residents agreed that step-3 training was very helpful for establishing their affinity for the phaco machine. If a resident is already well trained in the 2-position-pedal control for the I/A step, he or she should be more capable and confident of managing the 3-positioned pedal control for the phaco step. In step-5, we trained residents to deal with the separated nucleus fragments to enhance their ability of selecting the appropriate phaco power release. Reports showed nucleus dealing was always the most difficult part in phaco learning curve; 90% of residents did not reach proficiency until experience had exceeded 100 cases. In our observation, it was quite similar. The mean phaco parameter they used in that stage decreased obviously, but oral guidance may still need when dealing with the nucleus. Mean phaco power released was usually dependent on the nucleus rigidity, but the saving of phaco time and CDE was quite suggested as the improvement of surgical technique skills. Cumulative dissipated energy saving was accompanied by phaco time shortened in our study. The parameter of phaco time was generated only when the foot pedal was in the third position. This result means that at the end of SBSTP, residents have made great progress in releasing phaco power efficiently onto the nucleus and able to use more mechanical energy. The ineffective repeat of sculpturing because of uncertain of groove depth was less observed, which was also used to be a common source of wasting phaco time and energy at the beginning stage of the resident's practicing. On reviewing the records and behaviors of the last 30 cases performed by our residents, the phaco energy usage was quite proficient and the complication rate was in a low acceptable level. This result also shows that trainees in the SBSTP group can operate the machine smoothly and efficiently and show a progressive learning curve. According to this study, each resident performed a mean of 253 cases toward the end of observation, which was a competency number for them to achieve totally independent and skillful phacoemulsification cataract surgery. Most surgeries could be finished within 30 minutes compared with other reports up to 45 minutes on average.

All training procedures were carried out in patient eyes by trainees under supervision in order to ensure that patient safety remains the primary objective for both trainees and trainers. Most trainers are happy to transfer their skills, if no unexpected outcomes occur during the procedure. Our SBSTP is an effective, efficient, and safe approach to progressively master phaco skills for trainees without ECCE experience. In addition, the program offers a smooth and friendly teaching process due to increased control of the teaching procedure for the trainer. Thus, the step-by-step training program may enhance successful teaching phacoemulsification procedures and patient safety.

References
1. Badoza DA, Jure T, Zunino LA, Argento CJ. State-of-the-art phacoemulsification performed by residents in Buenos Aires, Argentina. J Cataract Refract Surg 1999;25:1651-5.
2. Blomquist PH, Rugwani RM. Visual outcomes after vitreous loss during cataract surgery performed by residents. J Cataract Refract Surg 2002;28:847-52.
3. Smith JH. Teaching phacoemulsification in US ophthalmology residencies: Can the quality be maintained? Curr Opin Ophthalmol 2005;16:27-32.
4. Carricido PC, Fortes AC, Mourão Pde C, Hajnal M, Jose NK. Senior resident phacoemulsification learning curve (corrected from cure). Arq Bras Oftalmol 2010;73:66-9.
5. Aslam SA, Elliott AJ. Cataract surgery for junior ophthalmologist: Are there enough cases? Eye 2007;21:799-801.
6. Mekada A, Nakajima J, Nakamura J, Hirata H, Kishi T, Kani K. Cataract surgery training using pig eyes filled with chestnuts of various hardness. J Cataract Refract Surg 1999;25:622-5.
7. Belyea DA, Brown SE, Rajjoub LZ. Influence of surgery simulator training on ophthalmology resident phacoemulsification performance. J Cataract Refract Surg 2011;37:1756-61.
8. Prakash G, Janjji V, Sharma N, Gupta K, Titijal JS, Vaipaye RB. Assessment of perceived difficulties by residents in performing routine steps in phacoemulsification surgery and in managing complications. Can J Ophthalmol 2009;44:284-7.
9. Taravella MJ, Davidson R, Erlanger M, Guiton G, Gregory D. Characterizing the learning curve in phacoemulsification. J Cataract Refract Surg 2011;37:1069-75.
10. Dooley JJ, O’Brien PD. Subjective difficulty of each stage of phacoemulsification cataract surgery performed by basic surgical trainees. J Cataract Refract Surg 2006;32:604-8.
11. Henderson BA, Ali R. Teaching and assessing competency in cataract surgery. Curl Opin Ophthalmol 2007;18:27-31.
12. Najjar DM, Awwad ST. Cataract surgery risk score for residents and beginning surgeons. J Cataract Refract Surg 2003;29:2036-7.
13. Haripriya A, Chang DF, Reena M, Shekhar M. Complication rates of phacoemulsification and manual small-incision cataract surgery at Aravind Eye Hospital. J Cataract Refract Surg 2012;38:1360-9.
14. Lee JS, Hou CH, Yang ML, Kuo JC, Lin KK. A different approach to assess resident phacoemulsification learning curve: Analysis of both completion and complication rates. Eye 2009;23:683-7.
15. Choi KS, Soo S, Chung FL. A virtual training simulator for learning cataract surgery with phacoemulsification. Comput Biol Med 2009;39:1020-31.
16. Oetting TA. Surgical competency in residents. Curr Opin Ophthalmol 2009;20:56-60.
17. Randleman JB, Wolfe JD, Woodward M, Lynn MJ, Cherwek DH, Srivastava SK. The resident surgeon phacoemulsification learning curve. Arch Ophthalmol 2007;125:1215-9.
18. Vaipaye RB, Kumar A, Dada T, Titijal JS, Sharma N, Dada VK. Phaco-chop versus stop-and-chop nucleotomy for phacoemulsification. J Cataract Refract Surg 2000;26:1638-41.
19. Gibson A, Boulton MG, Watson MP, Moseley MJ, Murray PI, Fielder AR. The first cut is the deepest: Basic surgical training in ophthalmology. Eye 2005;19:1264-70.
20. O’Brien PD, Fitzpatrick P, Kilmartin DJ, Beatty S. Risk factors for endothelial cell loss after phacoemulsification surgery by a junior resident. J Cataract Refract Surg 2004;30:839-43.

Cite this article as: Citation will be included before issue gets online***

Source of Support: Nil. Conflict of Interest: None declared.