

Complications in the first 10 phacoemulsification cataract surgeries with and without prior simulator training

Complicações nas 10 primeiras cirurgias de catarata por facoemulsificação com e sem treinamento prévio em simulador

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ABSTRACT | Purpose: To evaluate whether training medical residents with the Eyesi® cataract surgery simulator reduces the occurrence of intraoperative complications. **Methods:** This was a retrospective study in which the first 10 phacoemulsification surgeries performed by two groups of second-year ophthalmology residents were evaluated, during 2014 and 2015. The first Group consisted of seven residents from 2014 who had not had previous training with the simulator. The second Group was formed of seven residents in 2015, who had completed the C-level (intermediate) training with the simulator before beginning surgery on patients. We then compared these two groups regarding the frequency of occurrence of the four main intraoperative surgical complications: posterior capsule rupture, aphakia, and nucleus fragment dislocation into the vitreous, and extracapsular conversion. **Results:** A total of 140 surgeries were performed, 70 by Group 1 and 70 by Group 2. The total number of complications was 19 (27.14%) in Group 1 and nine (12.86%) in Group 2, and this reduction was significant ($p=0.031$). Fourteen (20%) surgeries in Group 1 and seven (10%) in Group 2 had complications. The complications were 13 posterior capsule ruptures (18.57%) in Group 1 and seven (10%) in Group 2; three eyes had nucleus fragment dislocations (4.29%) in Group 1, but only one (1.43%) in Group 2; two extracapsular conversions

(2.86%) occurred in Group 1 and one (1.43%) in Group 2; and there was one aphakia (1.43%) in Group 1. **Conclusions:** The training with the Eyesi® cataract surgery simulator significantly reduced the total number of intraoperative complications in the first 10 phacoemulsification cataract surgeries performed by ophthalmology residents.

Keywords: Simulation; Computer simulation; Phacoemulsification/adverse effects; Residents/education; Medical staff, hospital; Teaching

RESUMO | Objetivo: Avaliar se o treinamento de residentes médicos com o simulador de cirurgia de catarata Eyesi® reduz a ocorrência de complicações intraoperatórias. **Métodos:** Estudo retrospectivo em que foram avaliadas as primeiras 10 cirurgias de facoemulsificação realizadas por dois grupos de residentes de Oftalmologia do segundo ano, no período de 2014 a 2015. O primeiro Grupo foi formado por sete residentes de 2014 que não tiveram treinamento prévio no simulador. O segundo Grupo foi formado por sete residentes de 2015, que completaram o treinamento até o nível C (intermediário) no simulador antes de iniciar a cirurgia em pacientes. Em seguida, comparamos esses dois grupos em relação à frequência de ocorrência das quatro principais complicações cirúrgicas intraoperatórias: ruptura da cápsula posterior, afacia e deslocamento de fragmentos de núcleo para o vítreo e conversão para extracapsular. **Resultados:** Foram realizadas 140 cirurgias, sendo 70 pelo Grupo 1 e 70 pelo Grupo 2. O número total de complicações foi de 19 (27,14%) no Grupo 1 e nove (12,86%) no Grupo 2, e esta redução foi significativa ($p=0,031$). Quatorze (20%) cirurgias no Grupo 1 e sete (10%) no Grupo 2 tiveram complicações. As complicações foram 13 rupturas de cápsula posterior (18,57%) no Grupo 1 e sete (10%) no Grupo 2, três olhos com luxação de fragmento de núcleo para o vítreo (4,29%) no Grupo 1 e um (1,43%) no Grupo 2, duas conversões extracapsulares (2,86%) no Grupo 1 e uma (1,43%) no Grupo 2 e uma afacia (1,43%) no Grupo 1. **Conclusões:** O treinamento com o simulador de cirurgia de catarata Eyesi® reduziu significativamente o número total de complicações intraoperatórias nas primeiras

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10 cirurgias de catarata por facoemulsificação realizadas por residentes de oftalmologia.

Descritores: Simulação; Simulação por computador; Facoemulsificação/efeitos adversos; Residentes/educação; Corpo clínico hospitalar; Ensino

INTRODUCTION

The search for efficient methods to teach the art of surgery is constant, especially in the field of microscopic procedures, such as phacoemulsification cataract surgery⁽¹⁾. The better prepared the residents can be before starting their clinical work with patients, the more successful and possibly safer their future efforts will be⁽²⁾. Cataract surgery, when complicated, can lead to vision loss, and therefore an improvement in surgical techniques can be considered as an action to prevent unnecessary cases of blindness.

In wet labs, the resident usually performs the procedure using enucleated pig eyes. A disadvantage of such training is that the pig eye, although anatomically similar to the human eye, is not identical to it, especially regarding the greater elasticity of the anterior capsule, the soft lens, and the opacity of the cornea after death⁽³⁾.

As we know, virtual reality is a tool that enables an immersive and interactive experience based on three-dimensional images generated by a computer in real time⁽⁴⁾. This technology has potentially interesting applications in learning situations where repeated trials are needed to acquire abilities⁽⁵⁾. In an ophthalmological context, there are several especially appealing aspects of this approach: the possibility of building models with the correct geometry based on human anatomy⁽³⁾, the capability to substantially replicate the surgical environment allowing the use of both feet and both hands during the simulated surgery⁽⁶⁾, and the real consistency of tissues starting from biomechanical models, remarkably also including the appropriate tactile sensations⁽³⁾.

In phacoemulsification training, the simulator Eyesi[®] (VRmagic, Germany) has been highlighted as a teaching system based on virtual reality principles^(7,8). Its application to phacoemulsification includes its ability to address numerous clinical aspects of this procedure, including capsulorhexis, hydrodissection, and hydrodelineation, as well as the fragmentation and aspiration of the nucleus, aspiration of the cortex, and intraocular lens (IOL) implantation. This learning technology has been documented and validated in the literature^(7,8), but none of the cases that have been cited to date were performed in Brazil.

Repetitive training in the Eyesi[®] simulator performed by medical students has been shown to improve their skills in performing simulated phacoemulsification⁽⁹⁾. Studies regarding the use of this training system also show that it can result in a reduction of time and power phaco, a shorter learning curve of the surgical technique, and fewer intraoperative complications in surgeries performed by residents with experience in using this simulator⁽⁷⁾. The level of performance in this training system is highly correlated with the quality of outcome in live surgeries, and this equipment can be used not only for training but also to assess a surgeon's abilities⁽⁸⁾. Despite the high cost of the equipment, this particular simulation method appears to be cost-effective in learning phacoemulsification⁽¹⁰⁾.

Therefore, to test this proposition locally, this study aimed to evaluate whether previous training with the Eyesi[®] cataract surgery simulator can significantly reduce the occurrence of intraoperative complications in the first 10 phacoemulsification cataract surgeries performed by ophthalmology residents in a Brazilian medical school.

METHODS

After approval by the Botucatu Medical School - UNESP Institutional Review Board, we conducted a retrospective study in which the first 10 phacoemulsification surgeries performed by two groups of second-year ophthalmology residents (R2) were evaluated, during 2014 and 2015. The first group (G1) consisted of seven R2 in 2014 who had not had previous training with the simulator. The second group (G2) was formed of seven R2 in 2015, which was the year when the Eyesi[®] simulator was purchased by the medical school. G2 completed the C-level (intermediate) training with the simulator before beginning surgery on patients. All residents in these two groups, before their training with the simulator (G1) and before undertaking any phacoemulsification surgeries (G1 and G2), had obtained the same level of experience in cataract surgery, by having performed 10 extracapsular cataract surgeries (ECS) and assisting in some 20 phacoemulsification procedures. Each of the residents also had experience in performing about 15 pterygium surgeries.

All operated patients had grade 2 senile nuclear cataracts as defined by the Lens Opacities Classification System III. They also had good pupil dilatation and did not have any other systemic or ocular morbidity that contraindicated retrobulbar anesthesia.

All surgeries were supervised by an ophthalmologist prepared to solve intraoperative complications that might arise. The Stop and Chop phacoemulsification technique was used in all the procedures and employed the same phacoemulsifier (INFINITI® Vision System, Alcon®) and the same IOL (Abbott Sensar AR40e®).

For both sets of medical residents, the frequency of occurrence of the main intraoperative surgical complications was evaluated: posterior capsule rupture, aphakia, nucleus fragment dislocation into the vitreous, and ECS conversion. The resulting data were evaluated statistically, and Goodman's association test, which involves contrasts between binomial populations, was used to compare the number of complications in both groups⁽¹¹⁾. The significance level was 5% ($p < 0.05$).

RESULTS

Fourteen of the 70 surgeries performed by G1 had some type of complication (20%). The total number of these complications was 19 (27.14%), and they involved 13 posterior capsule ruptures (18.57%), one aphakia (1.43%), three eyes with nucleus fragment dislocation into the vitreous cavity (4.29%), and two conversions to ECS (2.86%), as detailed in table 1.

Seven of the 70 surgeries performed by G2 had complications (10%). The total number of these complications was nine (12.86%), consisting of seven posterior capsule ruptures (10%), one eye with nucleus fragment dislocation into the vitreous cavity (1.43%), and one conversion to ECS (1.43%), as shown in table 2.

A significant reduction in the total number of complications was observed when comparing intraoperative

complications between the G1 and G2 results ($p = 0.031$). All other parameters tracked were reduced in G2, but this difference was not significant. A comparison of the outcomes in both groups and the statistical significance metrics are shown in table 3.

DISCUSSION

After the acquisition of the Eyesi® simulator by the Botucatu Medical School - UNESP, in June 2015, it was established that all R2 should undergo training with this technology, by completing all C-level (intermediate) tasks, before starting clinical phacoemulsification practice with patients. This study aimed to evaluate the effectiveness of using this equipment as a phacoemulsification teaching tool, by analyzing the number of pre- and post-training intraoperative complications in procedures carried out by the G1 and G2 residents.

Every step in a phacoemulsification procedure depends on all the previous ones. Thus, if any early element of the procedure is performed with some imperfection, subsequent stages will have a good chance of not being carried out properly, increasing the risk of intraoperative complications⁽²⁾.

As expected, the number of such difficulties has been found to decrease progressively with appropriate training and supervision^(2,12-14). It is estimated that the chance of complications occurring declines by 1% for every fully performed surgery during training⁽¹³⁻¹⁵⁾. Therefore, more complications are expected to occur in surgeries performed by inexperienced surgeons, such as the R2, and their performance should improve with each completed procedure.

Table 1. Intraoperative complications in G1

Resident	Number of surgeries	Complicated surgeries	Number of complications	Posterior capsule rupture	Aphakia	Nucleus fragment dislocation	Extracapsular conversion
1	10	3	4	3	0	1	0
2	10	2	4	2	1	0	1
3	10	3	3	3	0	0	0
4	10	2	3	1	0	1	1
5	10	0	0	0	0	0	0
6	10	3	4	3	0	1	0
7	10	1	1	1	0	0	0
Total	70	14	19	13	1	3	2
%	100.00	20.00	27.14	18.57	1.43	4.29	2.86

Table 2. Intraoperative complications in G2

Resident	Number of surgeries	Complicated surgeries	Number of complications	posterior capsule rupture	Aphakia	Nucleus fragment dislocation	Extracapsular conversion
1	10	1	1	1	0	0	0
2	10	0	0	0	0	0	0
3	10	1	1	1	0	0	0
4	10	2	2	2	0	0	0
5	10	0	0	0	0	0	0
6	10	1	1	1	0	0	0
7	10	2	4	2	0	1	1
Total	70	7	9	7	0	1	1
%	100.00	10.00	12.86	10.00	0.00	1.43	1.43

Table 3. Comparison of complications between G1 and G2, and statistical significance

Group	Number of surgeries	Complicated surgeries	Number of complications	posterior capsule rupture	Aphakia	Nucleus fragment dislocation	Extracapsular conversion
G1	70.00	14.000	19.000	13.000	1.000	3.000	2.000
%	100.00	20.000	27.140	18.570	1.430	4.290	2.860
G2	70.00	7.000	9.000	7.000	0.000	1.000	1.000
%	100.00	10.000	12.860	10.000	0.000	1.430	1.430
p value		0.096	0.031	0.141	0.309	0.312	0.554

From the literature, we find that the rate of complications during phacoemulsification performed by a medical resident varies from 1.8% to 27.4%^(2,12-14). The rates in this study (i.e., 27.14% in G1 and 12.86% in G2) were compared with those in the literature. It should be noted that in the present study, data were used from only the first 10 surgeries performed by residents, not the total universe of surgeries, as is done in most studies. Thus, if the number of complications falls by around 1% with each performed surgery⁽¹²⁻¹⁵⁾, the incidence of complications in studies using the total universe of surgeries tends to be lower. This is an important factor that should be considered when comparing the number of complications found in this study with data in the current literature. It should also be borne in mind that the number of surgical complications can be quite different from the number of surgeries because more than one complication may occur in the same operation.

A study conducted some dozen years ago to assess the risks of cataract surgery performed by residents in a Brazilian university hospital showed that 13.4% of the phacoemulsification procedures performed by third year residents throughout the year had complications⁽¹⁶⁾. This value is smaller than the results produced by our G1 (20%), but higher than our G2 (10%) residents. However,

this earlier study included all operations performed by residents. In that investigation, residents started performing phacoemulsification only in the third year, and therefore had generally acquired more surgical skills in the first two full years of residence. In contrast, our study involved residents who began using this technique only in the middle of the second-year of residency.

The literature shows that posterior capsule rupture is the most common adverse event in procedures performed by residents, with this complication ranging in occurrence from 1.8% to 10.3% across various studies that evaluated between 164 and 1,400 surgeries throughout different stages of the learning curve^(14,17-20). In the present analysis, this was also the most frequently observed complication (18.57% in G1 and 10% in G2). It can be seen that after the introduction of the simulator, the posterior capsule rupture rate was closer to the value found in the literature, even considering that we evaluated only the first 10 surgeries performed with the new equipment. We should note that when considering only experienced surgeons, the posterior capsule rupture rate described in the literature is much lower, at between 0.45% and 2.5%⁽²¹⁻²³⁾.

The incidence of nucleus fragment dislocation into the vitreous during phacoemulsification varies from

0.3% to 1.1% in the literature, after excluding surgeons in training⁽²⁴⁾. This shows that the performance of the G2 residents, 1.43%, was closer to the rate of this complication described in the literature, unlike that of our G1 residents, who had a higher rate of 4.29%.

In an analysis of 755 surgeries performed by residents in their third year, the conversion rate to ECS was 1.9%. In the same study, the percentage of aphakia was 3.6%, nucleus fragment dislocation was 0.7%, and posterior capsule rupture was 6.7%⁽²⁵⁾. In comparison, the rates of these complications in our study were 2.86% for ECS conversions in G1 and 1.43% in G2; 1.43% for aphakia in G1 and zero in G2; 4.29% for nucleus fragment dislocations in G1 and 1.43% in G2; and 18.57% for capsule ruptures in G1 and 10% in G2. All G2 complication rates were closer to those found in the earlier study, while the G1 rates were higher. However, residents included in that study had already performed about 15 phacoemulsification surgeries, and the results of that investigation were based on all surgeries performed by third year residents.

In our present investigation, all the complications we analyzed were reduced almost by half for the G2 residents, showing the positive effect of prior training with the simulator. Still, this reduction was only statistically significant when considering the difference in the total number of complications, probably because the sample size was not sufficiently large to highlight corresponding changes in the other metrics we considered. A reduction in intraoperative complications after simulator training has already been highlighted in the literature⁽⁷⁾, but never for a rigorous trial in Brazil.

The old model of surgical education based on theoretical teaching, followed by training in the laboratory, the observation of experienced surgeons, and performing simpler surgeries before evolving to more complex ones has now been modified so that a resident's technical skills can be significantly improved before even entering the operating room. Therefore, virtual reality has been a material ally in reducing the anxiety of residents, while facilitating the often stressful task of their mentors^(3,6).

The significantly fewer complications that result after training with this simulation system can have a direct impact on the quality of the surgeries offered to patients and help reduce the costs of improving the lives of the visually impaired, all of which clearly justify the substantial cost of the high-tech equipment involved⁽¹⁰⁾.

This is the first Brazilian study on the use of the simulator as a teaching tool for phacoemulsification

cataract surgery. Although the limitations of this study include the retrospective design of its analysis, it would have been unethical to deprive a group of residents the use of this clearly productive learning tool, and consequently to submit patients to higher risks. Due to these significant ethical issues, it is clear that all residents in ophthalmology should have access to this technology and the training it can provide.

The outcome of this investigation is that experience using the Eyesi® cataract surgery simulator significantly reduced the total number of intraoperative complications in the first 10 phacoemulsification cataract surgeries performed by ophthalmology residents, compared to the outcome achieved by similar residents who lacked this particular training.

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