Time Parameters in Continuous Versus Pulsed Ultrasound Phacoemulsification: A Comparative Study

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Abstract

Purpose: To compare the effective phaco time, nuclear removal time as well as total surgery time when using continuous versus pulsed ultrasound in cataract removal by phacoemulsification.

Methods: A non randomized comparative study that included 106 eye of 106 patients who suffered from vision impairing cataract and were scheduled for cataract removal by coaxial phacoemulsification. Patients were subdivided into two groups; Group A (55 eyes) in which continuous mode was used and group B (51 eyes) in which the pulsed mode was used. Both were further subdivided into 5 subgroups according to LOCS III nuclear grading system. All patients had standard phacoemulsification with IOL implantation.

Results: There was no statistically significant difference between both groups as regards the nuclear removal time and the total surgery time. Effective phacoemulsification time (EPT) showed statistically significant difference between both groups in cases of cataract with nucleus grade 5 (p value =0.000).

Conclusion: It is advisable to use the pulse mode in cases of hard nuclei. These methods of power modulation aim at reduction of energy production with corneal protection and better visual outcome.

Key Words: Phacoemulsification – Pulsed UIS – Continuous.

Introduction

PHACOEMULSIFICATION has become one of the most significant innovations in cataract surgery through which the latter has advanced from a macro incision to a micro incision procedure with the consequent rapid wound healing and faster visual rehabilitation [1,2,3]. Despite the various energy sources, the ultrasound phacoemulsification is still the method of choice in cataract surgery being reliable for all cataract types [4].

Phacoemulsification depends on the relationships between the ultrasound energy, anterior chamber irrigation, flow rate and vacuum extraction of the nucleus. The phaco hand piece includes one or more piezoelectric crystals that convert electric energy to mechanical energy. The phaco power represents the combination of frequency and stroke length. The frequency is the speed of needle movement measured in Hertz and is usually set by the manufacturer beyond the surgeon's control however; the surgeon can control the stroke length. Increased frequency and stroke length are directly related to heat production hence the presence of an irrigation sleeve around the phaco needle [5].

The fluidic system comprises the irrigation that cools the phaco tip when it is oscillating limiting heat dissipation in addition to maintaining the anterior chamber pressure. The latter equilibrates with the water pressure produced by the irrigation bottle height. Aspiration comprises flow and vacuum. Flow describes the rate at which the fluid travels towards and through the probe tip and adds to the cooling effect. Vacuum describes the suction force that holds the material at the phaco tip. When the tip is occluded, vacuum rises and the flow rate is reduced to zero leading to removal of the lens fragment [6].

Ultrasound can be associated with corneal damage as well as endothelial cell loss [4,7]. So during the past years advances in technology had focused on power modulation in order to reduce the total energy delivered into the eye during surgery and improving fluidics to maintain chamber stability in face of the high vacuum and aspiration demands during cataract removal aiming at making cataract surgery safer and more efficient [8].

Classically, phacoemulsification was performed using continuous mode. This means that the phaco tip vibrates without interruption (always on) how-
ever this excessive power leads to chattering of the nuclear particles away from the phaco tip. This occurs due to the opposing forces of suction and tip oscillation causing repulsion. As the phaco power increases, the ultrasound frequency remains constant, it is the axial stroke length of the tip that generates the increased power [5,9].

The most basic form of power modulation is having a linear control when using the continuous mode. The further the pedal is depressed, the higher the phaco power. Maximum power is set and delivered between 0% and maximum preset power depending on how much the foot pedal is depressed [5,9].

This refinement aims at reducing the percentage of power used by limiting the phaco on time (OnT) i.e. the time during which the phaco tip vibrates while the phaco off (OffT) time is the time during which only irrigation aspiration occurs. The quotient between the OnT and OffT is called the duty cycle (DC). So, DC=OnT/(OnT+OffT). The idea of on and off time can be applied using the pulse and burst modes [5,7].

In the pulse mode setting, energy is delivered at regular intervals during which the OnT and the OffT are equal so the DC is 50%. For example, if the setting is 4 pulses per second this means that there are 4 discreet (125msec periods) of phaco OnT alternating with 4 (125msec periods) of phaco OffT during each full sec of time (1000msec) spent in foot position 3 [5,9]. Pulse mode cuts the phaco time in half. This shifts the balance between the opposing forces of suction and repulsion of the phaco tip thus improving the followability of the nuclear fragments being removed [10,11].

Pulse mode can also have linear control via the foot pedal [5,9].

Other modulations include burst mode where the surgeon can independently control the OnT and Off T. All the ultrasound bursts are equal in power and length. The surgeon controls the length of the rest period Off T by the stepping on the foot pedal in position 3. The off time is reduced to become a continuous mode according to pressure exerted on the foot pedal [10].

Power modulation also involves modifications in nuclear removal techniques that require less energy and more vacuum eg phaco chopping and its variants such as stop and chop, crater phaco chop, vertical chop as well as prechop [12].

**Material and Methods**

This is a non randomized comparative study that was conducted on 106 eyes of 106 patients with cataract who were divided into two groups. Cataract removal using phacoemulsification was done in both groups using continuous mode in group A and pulsed mode in group B. Both groups were further subdivided into 5 subgroups based on the nuclear grade.

Routine preoperative assessment was carried out where best corrected visual acuity was determined, slit lamp examination with nuclear grading as well as dilated fundus examination were performed. Nucleus grading was done using the lens opacities classification system III (LOCS III) where the nuclear opalescence and color is visualized via oblique slit lamp and compared with standard nuclear images.

Standard phacoemulsification was performed under topical anesthesia (Binoxintae Eye drops) using Geuder Megatron phacoemulsification machine. After prepping and draping the eye to be operated upon, a temporal clear corneal incision was performed with a 3mm keratome. A side port was made 90 degrees from the corneal incision by MVR 20G blade.

A standard capsulorrhexis was done followed by hydro dissection and delineation, most nuclei were removed using the chop and stop technique. The continuous mode was used in group A that comprised 55 cases while pulsed mode was used in group B that included 51 cases.

Effective phaco time (EPT), time of nucleus removal and total time of procedure were checked and documented.

**Statistical analysis:**

All the statistical analysis was done using the SPSS version 12. The demographic data of both groups were analyzed by calculating the mean, range and standard deviation. Comparison between demographic data in both groups was done using t-test and chi square tests to look for any statistically significant difference between both groups and to exclude any selection bias.

The nuclear grading in all cases was recorded and the percentage of each grade was calculated. t-test was done to compare both groups.

The nuclear removal time, EPT, as well as total time of surgery were recorded. Measure of the central density (mean) and measures of variation
The grading of nuclei in both groups can be demonstrated in graph 1. The difference between both groups was statistically insignificant ($p$ value $=0.299$). Grade 3 was the commonest among all grades in both groups.

The effective phaco time (EPT) in all groups is shown in Table (3) and Fig. (3). There was no statistically significant difference between both groups for nuclear grades 1-4. However, there was a statistically significant difference between both groups for nuclear grade 5 ($p$ value $=0.000$).

<table>
<thead>
<tr>
<th>Nuclear grade</th>
<th>Group</th>
<th>EPT ± SD</th>
<th>$p$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 1</td>
<td>A</td>
<td>2±1.16</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>3.67±2.08</td>
<td></td>
</tr>
<tr>
<td>Grade 2</td>
<td>A</td>
<td>4.85±5.66</td>
<td>0.623</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>3.71±2.43</td>
<td></td>
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<tr>
<td>Grade 3</td>
<td>A</td>
<td>10.85±7.91</td>
<td>0.767</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>10.31±4.76</td>
<td></td>
</tr>
<tr>
<td>Grade 4</td>
<td>A</td>
<td>17.57±16.4</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>25.23±13.21</td>
<td></td>
</tr>
<tr>
<td>Grade 5</td>
<td>A</td>
<td>63.4±3.362</td>
<td>0.000*</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>24.5±0.71</td>
<td></td>
</tr>
</tbody>
</table>

* Statistically significant.
The total surgery time in both groups is shown in Fig. (4). There was no statistically significant difference between both groups for all nuclear grades.

Fig. (4): Mean total time of surgery in both groups.

Discussion

Ultrasound phacoemulsification has become the method of choice in cataract surgery. However, the use of ultrasound can be associated with corneal damage namely endothelial cell loss and corneal burns [3,4,7]. The use of reduced energy levels has resulted in lower thermal damage to the cornea [8].

The single most important predictor of clear cornea and good visual outcome is the total amount of phaco energy delivered into the eye. With advances in phaco power modulation, surgeons can reduce the phaco time and power used in every case of cataract. For example, the use of phaco power in pulse or burst mode leads to decreased total phaco energy and increased nuclear removal efficiency [5].

In order to maximally decrease the EPT, the total phaco time and average phaco power must be decreased. The lower the EPT, the lower the energy delivered into the eye and thus the clearer the cornea with better visual rehabilitation [11].

The current study included 106 eyes of 106 patients divided randomly into two groups with different ultrasound power delivery mode. Continuous mode was used in group A while pulsed mode was used in group B. Both were further subdivided into 5 subgroups according the nuclear density.

Both groups were comparable as regards age and sex distribution. The main nuclear grade included in this study was grade 3 reflecting the better awareness about cataract and its surgery in the population so patients seek medical advice at a relatively earlier stage than before. However the distribution of other grades was comparable in both groups.

The nucleus removal time as well as total surgery time in both groups showed no statistically significant difference denoting that both methods can be equally used effectively in different nuclear grades.

The effective phaco time EPT is essentially the time taken to remove the cataract if continuous (100%) phaco power is used. Thus, EPT is the product of the total phaco time and the mean percentage phaco power. When the pulsed mode is used, this product has to be divided by the number of pulses to get the net EPT [11,13].

So, Effective phaco time (sec) = Total phaco time (sec) X Average phaco power (%)}

The EPT was statistically significant between both groups in nucleus grade 5 suggesting that the use of pulsed mode is preferred in removal of hard nuclei with less possibility of endothelial and thermal damage. There was no work published to study similar parameters in up to date literature. However, in a study published in 2007, Davison compared the Legacy 20000 Advanatc continuous and infiniti hyperpulse modes (Alcon Laboratories, Fort Worth, TX) as regards the average power, machine measured phaco time, total stop watch real phaco time BSS and corneal endothelial cell density loss [14]. Similarities were found between both machines for the continuous mode as regards the average power percent and phaco time.

In the hyperburst mode, a statistically significant difference for the average power percent and phaco time was found. Hence, it was concluded that both
machines perform similarly in continuous mode however, with infiniti there was total energy reduction of 66%. Both has the same stop watch measured time to complete phacoemulsification.

These results are consistent with those found in the current study as regards the total energy time, the use of hyperburst mode in Davison study was in a way comparable to the current results only in grade 5.

Chakarabati et al., conducted a study using a mean U/S time of 3.05 minutes when emulsifying hard cataracts using the pulse mode and Alcon Legacy machine. The current study showed a mean 5 minutes in grade 5. The difference could be attributed to the use of a different nuclear grading system, different phacoemulsification machine or nuclear removal technique [15].

Finally, Fine et al., found that effective phaco time showed slight increase with the grade of the nucleus [16] which is consistent with the current study up to grade 3 yet there was a marked change in EPT the harder the cataract gets. This could be attributed to the different time of clinical presentation time due to medical awareness as well as the nucleus grading system.

Conclusion:
Phacopower modulation has resulted in reduction of energy delivered into the eye with less corneal damage. The use of continuous or pulsed modes is equally effective however it is preferable to use pulsed mode in cases of hard nuclei. More studies on grade 5 nuclei should be conducted to verify these results yet, due to increased awareness, screening programs as well as early diagnosis and intervention, the percentage of this grade is progressively decreasing.

References