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Research Article

Cataract Surgery and Aqueous Humor pH Changes

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Abstract

Purpose: To compare aqueous humor pH changes during femtosecond (FS) laser-assisted cataract surgery with conventional cataract surgery.

Materials and methods: 29 eyes of 29 patients that underwent cataract surgery were studied. Group 1 included 15 eyes operated with a FS platform (Catalyst, Abbott Medical Optics) and Group 2 included 14 eyes that were operated with conventional phacoemulsification. Aqueous humor samples (0.1-0.15 ml) were collected through a paracentesis from each patient after nucleus fragmentation in Group 1 and after corneal incisions before the injection of viscoelastic in Group 2 and analyzed with a pH-meter.

Results: The mean pH was 6.53 ± 0.09 (range 6.42-6.70) and 7.42 ± 0.07 (range 7.28-7.48) in Groups 1 and 2, respectively. Differences between groups in this parameter were statistically significant ($p < 0.001$).

Conclusions: Photo disruption process in the femtosecond laser assisted cataract surgery lead to an acidic shift of the aqueous humor pH, as a result of the transformation of carbon dioxide to carbonic acid, in comparison with conventional phacoemulsification surgery. Further analysis of femtosecond laser assisted cataract surgery is necessary.

Keywords: *Aqueous humor; pH; Femtosecond laser-assisted cataract surgery*

Abbreviations: FS: femtosecond; US: ultrasound; AH: aqueous humor; BSS: balanced salt solution; IOL: intraocular lens; OVD: ophthalmic viscoelastic device; EPT: effective phacoemulsification time; SOD: superoxide dismutase

Introduction

Nowadays, cataract surgery is the most commonly performed ophthalmic procedure. It is estimated by the World Health Organization (WHO) that approximately 18 million cataract procedures are performed globally every year, which will increase to 24 million soon due to demographic changes, the aging population, and changes in indication for crystalline lens surgery [1]. As phacoemulsification became a safer and more established procedure, new technologies and surgical techniques are needed, one of these is the development of laser technology. It has been found that conventional phacoemulsification may potentially induce thermal damage [2] and thus a higher temperature in the anterior chamber which is proportional to the amount of the employed ultrasound (US) energy [3].

Recently, the introduction of femtosecond (FS) technology, based on the photo disruption of lens tissue, has provided significant advantages in terms of accuracy in cataract surgery [4]. However, it is not yet well studied how the process, which includes the formation of plasma and cavitation bubbles, can affect the biochemical composition of the aqueous humor.

Aqueous humor (AH) plays a major role in the physiology of the eye as it carries oxygen to the cells of the adjacent structures and removes waste products of the metabolism. AH protects against free radicals derived from the ultraviolet induced oxidation and facilitates cellular and humoral response to inflammatory and infectious processes. The AH pH in the human eye ranges from 7.32 to 7.60 according to different studies [5,6] and its rate of production is 1.5-4.5 μL/min. Human AH is a hyperosmotic fluid mainly composed by water, proteins, glucose, electrolytes as chloride, sodium and bicarbonate ions, and byproducts of the coagulation and anticoagulation pathways [5].

The AH biochemical composition may change in the presence of pathological conditions, such as cataract [7] and glaucoma [8], after application of topical medications [9,10] or an increased temperature during a surgical intraocular procedure.

The aim of our study is to compare aqueous humor pH values in patients during femtosecond (FS) laser-assisted cataract surgery with conventional phacoemulsification surgery.

Materials and methods

This prospective study was performed at Vista Monza (Italy), included 29 eyes of 29 patients with cataract surgery performed by a single surgeon. The study received the approval of the local ethics committee and the patients provided their informed consent. All procedures followed the tenets of the Declaration of Helsinki. Inclusion criteria for the study were sclerosis of the crystalline lens, absence of concurrent eye disease, no preexisting eye abnormalities, no history of eye surgery or trauma, and no systemic disease or pharmacological therapy in the last three months.

All patients were divided in two groups (Group 1 and 2). Group 1 included 15 patients (9 male and 6 female) with a mean age of 72.3 ± 4.2 (range 60-82) who underwent cataract surgery using the Catalyst FS platform (Abbott Medical Optics, Santa Ana, California). Group 2 included 14 patients (7 male and 7 female) with a mean age of 73.4 ± 5.3 (range 63-85) that underwent conventional phacoemulsification surgery. All patients were preoperatively dilated with tropic amide 0.28 mg and phenylephrine hydrochloride 5.4 mg and topical anesthesia was applied in all cases with benoxinate 4 mg/ml and lidocaine hydrochloride 4 mg/ml.

Surgical techniques

Patients included in Group 1 underwent the laser procedure outside the operating theatre. Predefined surgeon templates were used for selection of the anterior capsulotomy and fragmentation pattern. The Liquid Optics Interface (Abbott Medical Optics) was placed onto the eye, with a suction ring placed onto the patient´s sclera. The cornea was entirely inside the hollow optic that was filled with balanced salt solution (BSS) prior to docking. After ensuring that the eye was fixed, anterior capsulotomy, fragmentation, and paracentesis began. Patients who underwent conventional cataract surgery had continuous curvilinear capsulorhexis, hydro dissection and phacoemulsification following the standard procedure. After successful removal of the lens cortex an intraocular lens (IOL) was inserted into the capsular bag of all patients from both Group 1 and 2.

Sample collection

A sample of 0.1-0.15 mL of AH was aspirated through the paracentesis from the anterior eye chamber with a 25-gauge needle connected to a tuberculin syringe and placed into an electronic pH-meter (HANNA Instruments HI98128, Villafranca Padovana, Italy). The samples were collected at the beginning of the surgical procedure, after lens fragmentation in Group 1 and before the injection of the ophthalmic viscoelastic device (OVD) in Group 2.

Statistical analysis

Statistical analysis was performed using SPSS 19.0 software package. Data were presented as mean values and standard deviation (± SD). Differences between groups were tested using the Wilcoxon test. Statistical significance was set as $p < 0.05$.

Results

In Group 1, operated with the FS-laser platform, the mean time between docking and humor aqueous sample pH measurement was 7.75 ± 0.60 minutes (range 7-9 minutes). This time included: centration and docking, OCT images acquisition and program, capsulorhexis, nucleus fragmentation, paracentesis, then patients were moved to a different operating theatre, disinfection of periocular skin,

sterile sheet application and disinfection of conjuctival space and AH sample acquisition and measurement. The mean pH value in this group was 6.53 ± 0.09 (range 6.42-6.70) and thus more acidic compared to reference values of the human AH pH. However, the mean pH value in Group 2, treated with conventional phacoemulsification, was 7.42 ± 0.07 (range 7.28-7.48) and thus within the normal range of the human AH pH. Differences in pH between Groups 1 and 2 were statistically significant ($p < 0.001$).

Discussion

Femtosecond laser cataract surgery has been developed to avoid or minimize complications associated to conventional phacoemulsification, specifically to achieve a more precise capsulotomy, to provoke less damage to the corneal endothelium as the effective phacoemulsification time (EPT) is lower and consequently to less anterior chamber inflammation [11]. However, FS-assisted cataract surgery produces cavitation bubbles and carbon dioxide gas as a consequence of the photo disruption process of the crystalline lens tissue that lead to an acid shift of the aqueous humor pH. Recent studies note that femtosecond laser assisted cataract surgery rise up prostaglandin AH levels, especially during capsulotomy, that may be cause little intraoperative miosys [12,13].

The pH is a key regulator of the enzymatic activity and different cellular processes [14,15]. The AH has a physiologic pH of approximately 7.38 [16]. It is also well-known that AH pH can easily change under certain conditions like the use of pharmacological agents, injuries and infections because of the low concentration of common tampon systems. Veselovsky., *et al*. showed an acidic shift in the AH pH (7.46 to 5) in patients under treatment with anti-glaucoma medications [17]. Specifically, the progression of cataract provokes changes in the AH lipid peroxidation markers, superoxide dismutase (SOD), proteins and antioxidant levels related to the leakage of molecules from the lens capsule [18,19]. We tried to study chemical effects of carbon dioxide production during femtosecond laser assisted procedures. Henry´s law explains the behavior of the carbon dioxide in the AH and the chemical interactions between carbon dioxide and AH at constant pressure and temperature [20]. Carbon dioxide becomes carbonic acid, $H_2O + CO_2$ becomes H_2CO_3 that dissolves itself in H+ and HCO_3- lowering pH. The conversion from CO_2 to H_2CO_3 is directly proportioned to CO_2 pressure and time till a steady state. We only estimated time between the entire femtosecond laser procedures and AH sample measurement because ocular CO_2 pressure is not clinically relevant.

Our work found a statistically significant acidic shift in the group of patients operated with the FS laser platform than conventional phacoemulsification group. In any case, it should be considered that a low number of eyes were included in Group 1. An additional relative limitation of our study was the modification of the real AH pH due to the previous application of mydriatic agents in both groups. Potentially, acidosis may affect essential cellular processes, such as cellular migration, the flow of ions and fluids and inhibit mitochondrial function, leading to the generation of free-radicals [21]. FS laser cataract surgery leads to an acidification of the AH pH compared to control cataract eyes. It still remains unclear if this acidic shift may significantly affect the function of the adjacent structures and the interaction with topical eye medication such as prostaglandins. In our opinion this acid shift has no clinical effects because of the little time between acidification and filling the anterior chamber with balanced salt solution anterior during femtosecond laser surgery.

Conclusion

Our study discovered that the photo disruption process in femtosecond laser assisted cataract surgery produced cavitation bubbles. Cavitation bubbles led to an acid shift of the aqueous humor pH as a result of the transformation of carbon dioxide to carbonic acid.

Further research is needed to confirm our results and for better underline the role of cavitation bubbles on aqueous humor pH changes.

	Group 1 (femtosecond laser surgery)	Group 2 (conventional phacoemulsification surgery)
Number of Patients	15	14
Age (Years)	72.3 ± 4.2 (range 60-82)	73.4 ± 5.3 (range 63-85)
AH pH	6.53 ± 0.09 (range 6.42-6.70)	7.42 ± 0.07 (range 7.28-7.48)

Table 1: *Data summery.*

Bibliography

1. Koopman S. "Cataract surgery devices-global pipeline analysis". Competitive landscape and market forecasts to 2017. London, UK: Global data, accessed March 18 (2014).
2. Nagy ZZ., *et al*. "Initial clinical evaluation of intraocular femtosecond laser in cataract surgery". *Journal of Refractive Surgery* 25.12 (2009): 1053-1060.
3. Nagy ZZ., *et al*. "Comparison of intraocular lens decentration parameters after femtosecond and manual capsulotomies". *Journal of Refractive Surgery* 27.8 (2011): 564-569.
4. Suzuki H., *et al*. "Temperature in the anterior chamber during phacoemulsification". *Journal of Cataract & Refractive Surgery* 40.5 (2014): 805-810.
5. Goldschmidt M. "Heidelberger Berichte S Zus". *Heidelberger* (1925): 191-197.
6. Sharma RG., *et al*. "A clinical evaluation of oxygen and carbon dioxide values and pH in the human aqueous humor in normal and cataractous eyes". *Indian Journal of Ophthalmology* 31.5 (1983): 525-527.
7. Dias PL. "Postinflammatory and malignant protein patterns in aqueous humor". *British Journal of Ophthalmology* 63.3 (1979): 161-1644.
8. Tripathi RC., *et al*. "Quantitative and qualitative analysis of transferrin in aqueous humor from patients with primary and secondary glaucoma". *Investigative Ophthalmology & Visual Science* 33.10 (1992): 2866-2873.
9. Bito IZ., *et al*. "The effects of autonomic drugs on mitosis and DNA synthesis in the lens epithelium and on the composition of the aqueous humour". *Experimental Eye Research* 4.1 (1965): 54-61.
10. Reyes MR., *et al*. "The effect of antiglaucoma drugs on rabbit aqueous humor proteins determined by gel electrophoresis". *Journal of Ocular Pharmacology and Therapeutics* 14.3 (1998): 229-237.
11. Abell RG., *et al*. "Anterior chamber flare after femtosecond laser-assisted cataract surgery". *Journal of Cataract Refract Surgery* 39.9 (2013): 1321-1326.
12. Schultz T., *et al*. "Changes in prostaglandin levels in patients undergoing femtosecond laser-assisted cataract surgery". *Journal of Refractive Surgery* 29.11 (2013): 742-747.
13. Schultz T., *et al*. "Prostaglandin release during femtosecond laser-assisted cataract surgery: main inducer". *Journal of Refractive Surgery* 31.2 (2015): 78-81.
14. Fischbarg J and Lim JJ. "Role of cations, anions and carbonic anhydrase in fluid transport across rabbit corneal endothelium". *Journal of Physiology* 241.3 (1974): 647-675.
15. Boron W. "Regulation Intracellular pH". *Advance in Physiology Education* 28.1-4 (1981): 160-179.
16. Edelhauser HF., *et al*. "Adler's Physiology of the Eye". 10th *ed. U.S. Mosby* (2003): 89
17. Veselovský J., et al. "Change in the pH aqueous humor after administration of anti-glaucoma agents in rabbits *in vivo*". *Ceská a slovenská oftalmologie* 57.4 (2001): 219-225.
18. Miric DJ., "Influence of cataract maturity on aqueous humor lipid peroxidation markers and antioxidant enzymes". *Eye* 28.1 (2014) 72-77.
19. Sawada H., *et al*. "Oxidative stress markers in aqueous humor of patients with senile cataract". *Current Eye Research* 34.1 (2009): 36-41.
20. Battino R and Clever HL. "The solubility of gases in liquids". *Chemical Reviews* 66.4 (1966): 395-463.
21. Siesjo BK., *et al*. "Acidosis-related damage". *Advance in Neurology* 71 (1996): 209-233.

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