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Cataract, phacoemulsification and intraocular pressure: Is the anterior segment anatomy the missing piece of the puzzle?

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ABSTRACT

Cataract extraction is a safe and effective surgery that has a lowering effect on the intraocular pressure. The specific mechanisms for this effect are still unclear. A direct inflammatory effect on the trabecular meshwork, alteration of the blood aqueous barrier, changes in the ciliary body and mechanical changes of the anterior segment anatomy are the key to understand cataract surgery and it's effects on aqueous humor dynamics. Additionally, with the advent of AS OCT, changes in the anterior segment of the eye have been studied and several parameters (such as lens vault, angle opening distance and anterior chamber depth) have been identified as predictors of intraocular pressure change. In eyes with narrow angles there is a greater drop in intraocular pressure after cataract surgery and it is correlated with parameters related to anterior chamber space. It is safe to affirm that cataract surgery is an important part of the modern glaucoma treatment and evidence should be analyzed as part of a bigger picture in order to more accurately understand its clinical relevance.

1. Introduction

Cataract extraction is a safe and effective surgery. Many studies have noted that cataract extraction also has a clinically significant role in the control of co-morbid glaucoma (Brown et al., 2014; Masis et al., 2017b; Shah et al., 2016; Vizzeri and Weinreb, 2010; Zhang et al., 2015). Lens extraction decreases the pressure within the eye, and intraocular pressure (IOP) is the most important controllable risk factor in glaucoma. The potential physiological mechanisms by which cataract surgery can control IOP are yet to be fully elucidated.

Anterior segment anatomy (in particular, the angle structures) and changes to this anatomy—on microscopic and ultrastructural levels—are likely involved in the key mechanisms related to IOP elevation and glaucoma pathophysiology. This anatomy and change in anatomy also probably account for the correlation between cataract surgery and the IOP effect in glaucoma and non-glaucoma patients.

For glaucoma, there have been several theories related to the mechanisms for its development but there is increasing evidence that glaucoma is not caused by a single mechanism, and that there are several factors including the anatomy of the anterior chamber which can influence the dynamics of aqueous humor outflow, again mainly in eyes with angle closure glaucoma (ACG) and angle closure suspicion. (Nongpiur et al., 2017; Zebardast et al., 2016).

There is increasing evidence showing that in eyes with ACG, phacoemulsification is an effective treatment, however, for open angle glaucoma (OAG) the clinical impact remains controversial. Our perspective in this review is that the anatomy of the anterior segment and its changes after surgery are also the reasons for the IOP effect after cataract surgery in eyes without angle closure.

1.1. Epidemiological considerations

Glaucoma has a prevalence of 3.54% for the global population between the ages of 40 and 80 years old. The prevalence of glaucoma and its subtype distribution is strongly dependent on ethnicity/geography; for example, in Africa the prevalence of primary OAG is higher (4.20%) compared to other continents and in Asia the prevalence of primary ACG is the highest (1.09%) among all continents(Tham et al., 2014). The number of people with glaucoma worldwide has been estimated to be 64.3 million, projected to increase to 76.0 million in 2020 and 111.8 million in 2040(Tham et al., 2014).

Glaucoma is a progressive disease that does not always result in blindness. The risk for low vision and blindness for those with glaucoma has yet to be studied in a prospective long-term manner analyzing the effect on quality of life, although several epidemiology studies have already provided relevant information in different populations. Results from the Advanced Glaucoma Intervention Study (AGIS) (Chen, 2003) gave some indication of the long-range risk of blindness. In this U.S.-

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Abbreviations

ACA	anterior chamber area
ACG	angle closure glaucoma
AGIS	Advanced Glaucoma Intervention Study
ACV	anterior chamber volume
ACW	anterior chamber width
AL	axial length
AOD500	anterior chamber depth 500 μm from the scleral spur
AOD750	anterior chamber depth 750 μm from the scleral spur
AS- OCT	anterior segment optical coherence tomography
BAB	blood–aqueous barrier
ECCE	extracapsular cataract extraction
FDA	US Food and Drug Administration
IOP	intraocular pressure
IT2000	iris thickness at 2000 μm
IT750	iris thickness at 750 μm
LP	lens position
LT	lens thickness
LV	lens vault
OAG	open angle glaucoma
PAS	peripheral anterior synechiae
RLP	relative lens position
TISA 500	trabecular-iris space area at 500 μm from the sclera spur
TISA 750	trabecular-iris space area at 750 μm from the sclera spur
TM	trabecular meshwork
WHO	World Health Organization

based group of 186 patients (82% white) with treated OAG, including normal tension glaucoma, pseudoexfoliation glaucoma, and pigmentary glaucoma, with a follow up of 15 years, there was an estimated 14.6% of patients with unilateral blindness and 6.4% with bilateral blindness, with blindness defined as visual field loss to 20 central degrees or visual acuity ≤20/200. Compared to OAG, it is estimated that patients with ACG have on average three times greater risk of suffering from bilateral blindness and severe visual impairment (Quigley and Broman, 2006).

1.2. Cataract: a public health problem

According to the global data on vision impairment published by the World Health Organization (WHO), the main causes of visual impairment are uncorrected refractive error (43%) and cataracts (33%) (Pascolini and Mariotti, 2012). Moreover, cataract is the leading cause of blindness (51%) followed by glaucoma (8%). Southeast Asia is the most affected region with a proportion of avoidable blindness (blindness which could have been either treated or prevented by known, cost-effective means) of 28%, followed by the Western Pacific at 26%, Africa at 16.6%, Eastern Mediterranean at 12.5%, Central and South America at 9.6% and Europe at 9.6%.

When evaluating the social impact of pathologies producing visual impairment, it is important to take into account the degree of detriment to a person's quality of life as well as socio-economic impact at different levels of visual loss, particularly in vulnerable populations such as the elderly.

A study published by Frick and colleagues showed, based on data from the United States, that blindness and visual impairment are significantly associated with higher medical care expenditures, a greater number of informal care days, and a decrease in health utility (Frick et al., 2007). The annual economic impact includes $5.5 billion spent for medical care and the estimated value of informal care, as well as a loss of more than 209,000 quality-adjusted life years (Frick et al., 2007).

Vision impairment has long been recognized as a risk factor for falls (Patino et al., 2010/2). In a prospective study evaluating fall risk in patients over 65 years with cataract (Palagyi et al., 2016) it was determined that there is a substantial rate of falls and fall injury in older adults with cataract who were awaiting surgery, with an associated poorer health-related quality of life. There was an incidence of 1.2 falls per person-year in the cohort of patients waiting for cataract surgery; 51.7% of the falls resulted in injuries.

In a study based on Medicare data from 2002 to 2010, Tseung and colleagues determined a comorbidity of glaucoma in cataract patients of 19.1% (Tseng et al., 2012). Since both glaucoma and cataract are intrinsically correlated with age and both are main causes of visual impairment worldwide, a robust analytic review of the evidence for the role of cataract surgery in glaucoma therapy would be helpful to guide further clinical studies.

2. Fluidics and ultrasound: a revolution in eye surgery

In early 1966, the first primitive phacoemulsifier was released (not the first commercial version approved for human use) after years of basic science research performed by Dr. Charles Kelman (1994). After several animal models and clinical trials, the first commercial version of this small incision cataract extraction tool became available in 1970. This surgical development along with discoveries in intraocular lens technology, viscoelastic material for surgical use, and microsurgical instruments led to what we know now perceive as modern cataract surgery.

In phacoemulsification, the cataractous lens is removed by the application of high-energy ultrasound. A combination of mechanisms including direct action of the ultrasound vibrating tip against tissue and indirect cavitational effects are the principles for tissue destruction and cataract emulsification (Packer et al., 2005/2). The phacoemulsification surgical hand-piece incorporates a transducer for converting high frequency ultrasound into mechanical vibrations, and the system is supported by an irrigation-aspiration system (also integrated into the hand-piece) which maintains both volume and temperature in the eye during the surgery (Packer et al., 2005/2).

Phacoemulsification has been shown to decrease IOP. The specific mechanism responsible for the effect of the surgery on IOP remains, however, controversial.

3. Effect of phacoemulsification on intraocular pressure

3.1. Mechanisms for intraocular pressure lowering

Phacoemulsification is not the only type of surgery that lowers IOP; older forms of surgery, which do not involve ultrasound, show similar effects. With extracapsular cataract extraction (ECCE), there is also similar IOP lowering and change in anterior segment anatomy. In 2016, the results of a randomized controlled clinical trial comparing phacoemulsification and manual small incision cataract surgery (a subtype of ECCE) were reported (Sengupta et al., 2016). At six months follow up it was determined that both surgical procedures produced similar changes in anterior chamber parameters and similar drops in IOP compared to baseline.

The effect of phacoemulsification on IOP may be different among patients, time of the day pressure was assessed and follow up periods. It was suggested that the surgery may produce IOP lowering fluctuations during nocturnal period in patients with primary angle closure glaucoma (Aptel et al., 2016). With current evidence, we can't conclude in detail which patients are most likely to have a sustained IOP reduction. Even in specific groups divided by glaucoma diagnosis, the response to IOP is very heterogeneous; however, it has been shown that there is a strong correlation of the IOP change measured in different time periods and our analysis suggests that 6-month data is representative of the