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Correlation of Age-Related Cataract Density Graded by the Scheimpflug Imaging System with Visual Function and Phacoemulsification Energy

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A B S T R A C T

The purpose of this study is to investigate the relationship between lens density in age-related cataract and best-corrected visual acuity (BCVA) and the impact of cataract grade assessed via 3D lens densitometry by Pentacam Nucleus Grading System (PNS) on Phacodynamics (phaco-time and phaco-energy). To achieve the aim 55 patients with age-related cataract were evaluated. Lens density was assessed using the PNS. BCVA was tested with Snellen chart. Surgery was performed with no adjustment of parameters and phaco-energy-time was monitored. The correlations between the lens density, BCVA and phaco-energy/time were analyzed. There was a negative linear correlation between lens density and BCVA and positive correlation between density and total dissipated phaco-energy. The cataract PNS grade negatively correlated with the visual function. The positive correlation was found between the lens density and phacoemulsification time and energy. The Scheimpflug optical densitometry offers objective grading and can be used both for prediction and for monitoring of the condition. PNS enables to predict phacodynamics and the most suitable phaco settings to minimize the disturbance of the eye during surgery.

Key words: *lens density, Scheimpflug imaging, cataract, phacoemulsification, classification*

Introduction

Cataract is a major public health issue in an elderly population worldwide. It is the most prevalent condition in patients attending optometric and ophthalmologic practice with cataract extraction remaining the most commonly performed eye operation.

The human lens undergoes a continuous process of growing and is exposed to the cumulative effect of radiation, oxidation and other factors. As a result in an aging lens features such as follows occur: fall in light transmission by the lens, increased light scatter, increased spectral absorption and increased lens fluorescence. Thus aging combined with the variable noxious factors induce typical changes in lens characteristic, finally leading to cataract development. As older people comprise the fastest growing sector of developed countries' population, dealing with cataract presents an important up-to-date and future issue.

Accordingly, reliable assessment of cataract is vital, both in the respect to cataract classification and quantitative measurement. The exact grading system is imperative for investigating the possible risk factors of cataract formations, documenting progression of cataract, evaluating of anti-cataract drugs as well as for epidemiologic studies. In clinical practice, for patient the reasonable monitoring of his condition is of high importance, enabling inform one about the progression of his cataract and treatment methods.

In cataract surgery, the knowledge about lens density could help to enhance the ability to estimate the ultrasound power needed during the phacoemulsification. Pre-operative classification could lead to better organized, customized operative plan. The optimization in phaco-energy dissipated in patients' lenses could potentially lead to better visual outcomes and lower traumatization of the eye. Lower levels of ultrasound power may help reduce endothelial cell damage and result in clearer post-operative corneas. Therefore it is reasonable to plan the operation with the lowest level of ultrasound energy needed to ex-

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tract cataract with certain density profile. Moreover, potential pitfalls could be anticipated and challenging cases recognized before the operation, which enables adaptation of the technique and achieving better outcomes.

Clinically, several methods can be used to evaluate cataract. Those can be classified either as subjective or objective ones. The former includes Wisconsin system[1], Wilmer system[2], Oxford system[3] and Lens Opacities Classification System III (LOCS III)[4], with LOCS III being the most recognized. Although the LOCS III is well established and proved to have good reproducibility in cataract grading[5], it still suffers from limitations rooted from its subjective nature. Subjective methods generally are based on clinical measurements such as best corrected visual acuity, slit-lamp lens assessment (nuclear opacity, nuclear color), and slit-lamp photography. Those parameters can be influenced by factors such as different slit-lamp settings, inter and intra observer inconsistencies which lead to poor reliability of method. Beside all aspects mentioned above, the subjective techniques are also time-consuming which exclude them from a routine eye care practice.

Thus, an easy objective method is desirable, especially in modern clinical practice, where a patient is examined by various observers at each visit and follow up based on subjective grading cannot give reliable information about progression of the disease.

Objective methods are based on slit image photography according to Scheimpflug principle together with densitometric image analysis. The Scheimpflug principle was first described by an Austrian naval cartographer Theodor Scheimpflug in 1904, defining a concept of optical imaging for obliquely tilted objects. Thanks to specific settings, maximally possible depth of focus is achieved and the image distortion is minimized. In a conventional camera, the lens and image planes are parallel to each other and a plane of focus is parallel to these. In such a setting only a planar subject parallel to image plane can coincide with the plane of focus and thus will be rendered sharply. Oppositely, in tilted objects, where the subject plane is not parallel to the image plane, only a small region along a line intersecting the plane of focus (Scheimpflug line) is sharp. The out of focus images are not suitable for any further analysis, therefore a different approach is employed to overcome this limitation. Scheimpflug designed the setting in which image plane is inclined to lens plane, which results in change of focus plane along the Scheimpflug line. All objects on the line will be completely in focus.

The Scheimpflug principle was introduced into ophthalmology by Drews[6], Brown[7], Hockwin and Dragomirescu[8] with the main purpose to acquire a clear image of the anterior eye segment. For lens densitometry has been Scheimpflug image used in several system, including Oxford Scheimpflug System[9], the Topcon SL-45[10,11], the Zeiss Scheimpflug video camera[12] and Nidek EAS-1000[13].

The latest development among commercially available Scheimpflug imaging system is Pentacam (Oculus, Wetzlar, Germany). In Pentacam a rotating Scheimpflug camera is employed to allow for capturing up to 100 slices within one sweep around the central axis of the lens. Therefore, the image is obtained in nearly each of the 180 meridians and a complete three dimensional view of the whole anterior segment from the anterior corneal surface up to posterior lens surface can be created. The incorporated software can run the lens density analysis based on the evaluation of light scattering characteristic within the lens volume. As density fluctuations are the main contributions to light scattering in human lens, the documentation of light scattering profile together with the measurement of reflectance and transmittance, enables to compute the lens optical density.

The performance of Pentacam examination is very easy and rapid with the measurement completed within 2 seconds. The facts that the measurement is independent on observes' skill contribute to higher reliability. Furthermore, any inter-observer differences in interpretation are excluded and thus high objectivity is achieved. Both repeatability and validity of lens densitometry derived from Pentacam was assessed by several studies and has been showed as high[14].

The Pentacam Nucleus Staging (PNS) function is incorporated in the Pentacam software and can serve as an easy grading system. The volume of opacification is assessed, the mean and maximum optical density is measured and the results are compared against the internal nomogram. The result is a classification of each case as one of 6 stages, starting with 0 and going up to 5. Additionally, a clear three-dimensional reconstruction of lens with the visible areas of opacification is offered.

Patients and Methods

We analyzed 55 eyes of 55 patients with age-related cataract from the Saint Anne's Faculty Hospital, Brno, Czech Republic, who underwent phacoemulsification from November 2012 until March 2012. The age of patients was 53 to 93 years, with the average age 75.9 years (SD=8.4). Into the study group 26 male and 29 female was enrolled. The distribution of age and gender is shown in Table 1. Inclusion criteria were: age-related cataract, the absence of other ocular abnormalities, the average ametropia was in the range from –8.5 to +2.25 Dpt, with the average refractive power 0.9 Dpt (SD=1.8). On each patient a comprehensive eye examination was performed, including the best corrected visual acuity (BCVA) on Snellen charts under natural light environment, slit-lamp examination, fundus examination, ultrasound axial length measurement, non-contact tonometry and the Scheimpflug lens density measurement on Pentacam HR (Oculus, Wetzlar, Germany). The lens density was measured by one examiner, after pupil dilatation (45 minute after instillation of tropicamide 1%). Two successive measurements were obtained in each eye and the mean value was used. However, the reproducibility was checked in the first 15 cases and it was shown that in the »PNS« value there was 93.3% agreement, and with the Average and Maximum density the agreement was 96 and 94% respectively.

TABLE 1
DISTRIBUTION OF AGE/GENDER IN RESPECT TO PNS GRADE AND THE NUMBER OF EYES ANALYZED IN EACH PNS GRADE.

Characteristic	Patients	PNS Grade				
		0	1	2	3	4
Age (years)	Number of eyes	7	27	15	4	2
50–59	4	0	1	0	0	0
60–69	7	1	7	1	1	0
70–79	27	3	12	9	1	1
80–	17	3	7	5	2	1
$\overline{X}$ (SD)	75.9 (8.4)	78.0 (6.9)	73.5 (9.3)	78.0 (6.3)	77.5 (7.3)	82.0 (15.5)
Gender						
Male	26	6	10	8	3	2
Female	29	1	17	7	1	0

PNS – Pentacam nucleus staging system

Scheimpflug image of the lens was analyzed and the values we recorded were as follows: the average lens density, the maximum lens density and the PNS grade. The phacoemulsification was performed in all patients without any changes in parameters. The surgeon has no information about the density values in any patients. During the surgery the phacoemulsification time and power was recorded. Those two parameters were further converted similarly as into another studies into the effective phacoemulsification time using the following formula[15]: EPT=(Average phaco-power * phaco-time)/100 [%].

The statistical analysis was performed using the Statistica™ 10 (StatSoft, Inc., USA) software. A p-value less than 0.05 were considered to be statistically significant. The relationships between variables were assessed using the Spearman correlation coefficient.

Results

For the total of 55 patients the measured parameters was recorded. The Scheimpflug images obtained for each grade are showed in Figure 1.

We observed no relationship between the maximum density measured by Pentacam and the corresponding PNS grade (r=0.082; p=0.654). However, there was a positive correlation (Figure 2) between the average lens density and the PNS grade (r=0.501; p<0.000). This suggest, that the maximum opacity is not a single relevant parameter, but also the other features play an important role, such as the total volume of opacification or its location within the lens.

The statistically significant correlation has been found between BCVA and PNS grade of cataract (r=0.451;

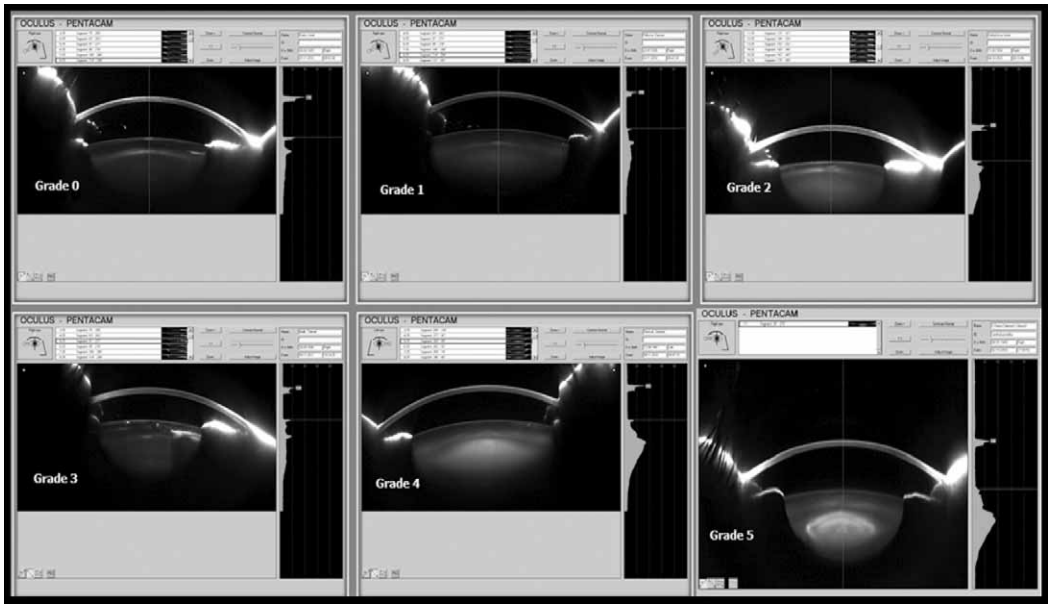

Fig. 1. Pentacam Scheimpflug images age related cataract. One image for each grade is shown.

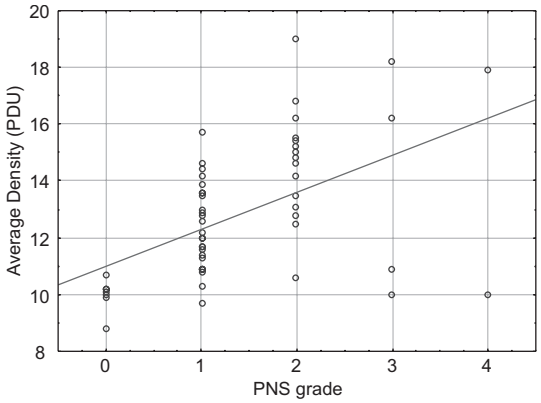

Fig. 2. Relationship between average lens density displayed in Pentacam Density Units (PDU) and PNS grade of cataract (r= 0.501, p<0.000).

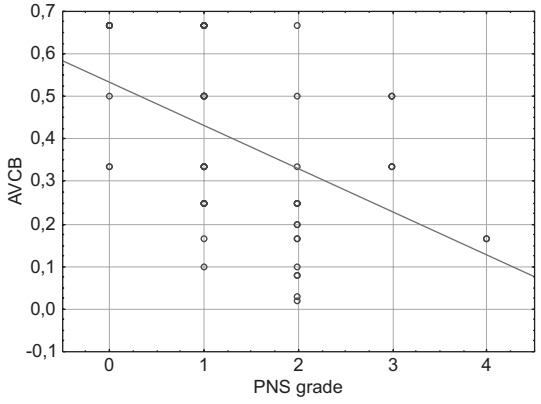

Fig. 3. Relationship between best corrected visual acuity (BCVA) and PNS grade of cataract (r=0.451, p<0.000).

p<0.000) with the relationship displayed in Figure 3. The higher PNS grade was associated with a decreased BCVA.

There is a correlation between the phacoemulsification time and PNS (r=0.531; p=0.000) but only a weak correlation between the phacoemulsification power and PNS (r= 0.393, p=0.003).

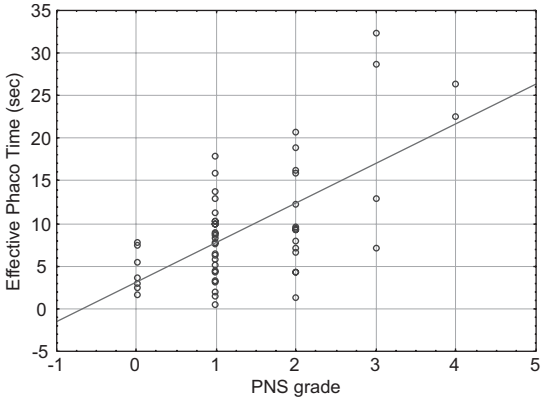

Fig. 4. Relationship between effective phaco time and PNS grade of cataract (r=0.631, p<0.000).

Moreover, highly positive linear correlation has been identified between effective phacoemulsification time (EPT) and PNS with the Spearman correlation coefficient 0.631 (p<0.000) (Figure 4).

Discussion

Several studies were undertaken with the common aim to compare the correlation of features of cataracts with visual function and phacoemulsification parameters.

Pei et al.[16] has demonstrated the correlation between lens density measured at Pentacam and the best corrected visual acuity (BCVA). The correlation between BCVA and PNS found by Pei was higher (r=0.867) compared to our results (r=0.451). This can be explained by the fact that LogMAR Visual acuity which was used in the former study is more sensitive method compare to Snellen chart acuity used in our study. Moreover, only pure nuclear cataract was included in the Pei's study. The nuclear opacification is responsible to higher deterioration in vision compare to other cataract type (cortical, posterior subcapsular). In our study, we did not discriminate between cataract types. However, when using the PNS classification, the correlation was stronger, suggesting that PNS automatically calculates with the »significant area« or »region of interest«, emphasizing the nuclear area, which has been confirmed as an area is of biggest importance to the visual function[15,17].

Anyway, any assessment of best corrected visual acuity has only a limited predictive value in the estimation of patient's actual vision impairment caused by cataract. Cataract patients usually present with a wide variety of symptoms including lowering of contrast sensitivity, altered color vision and troubles with glare[18]. Out of those features, contrast sensitivity can be regarded as a sensitive indicator of quality of vision as today's life brings many task performed under dim surrounding.

The correlation between contrast sensitivity and lens density derived from Scheimpflug image was evaluated by Grewal et al.[15]. They observed the relationships in respect to the average and nuclear lens density and in both cases the significant correlation was found, with stronger correlation of nuclear density.

Moreover, to quantify the functional limitations caused by cataract, standardized questionnaires have been developed. Those questionnaires are designed to measure the impact of cataract related vision deterioration to the ability of performing daily activities. The most recognized is the VF-14, which consists of 14 questions, relating to various vision-dependent activities. Despite it has been proved that this is a reliable, valid and responsive instrument for quantifying functional impairment, it is only rarely used by practicing ophthalmologist[19]. One spent by administration to the patients and evaluation.

Therefore, a study comparing objective lens density measurement with the subjective evaluation of visual impairment would be desirable.

Regarding the phaco-parametrers, Benčić et al.[20] described clinical importance of pre-operative classification of cataract for phacoemulsification. They used the LOCS III system to grade the cataract and recorded phacoemulsification time and power. Both intraoperative characteristic correlated positively with the nuclear opalescence and color.

The recent studies use Scheimpflug imaging for measuring lens density and the effect on operation is monitored. Kim et al.[21] have evaluated the relationship between lens density and phacodynamics in patients with nuclear cataract and reported a positive linear correlation between Scheimpflug measured lens nuclear density with phacoemulsification time and energy.

Nixon et al.[22] have proved that pre-operative adjustment of the phaco parameters based at cataract grade assessed by Pentacam (Pentacam Nuclear Staging) have improved overall efficiency. Phaco parameters such as energy, time and fluid (balanced salt solution) have been reduced significantly.

Grewal et al.[15] analyzed also the correlation of nuclear and average lens density with phacoemulsification time and power. The correlation has been found stronger with nuclear density, which has been explained by the assumption that most of the phacoemulsification energy is expended on removing the nucleus. Comparing to this study we obtained a similar results with the respect to EPT and lens density correlation ($r=0.631$ our study, $r=0.597$ in[15]). The difference was in the classification of nuclear density, when in our study a PNS software tool was used while a different approach was used in the former study. However the results show high similarity.

They also highlight the importance of lens imaging in challenging cases such as capsular bag distorsion syndrome or posterior capsule opacification.

Conclusion

With a demographic shift towards the higher age, the cataract is becoming a current issue with increasing patients' expectations both in the preoperative phase and during the operation.

Scheimpflug lens densitometry is a useful tool in both phases. It allows tracking even subtle changes in lens density over time and is independent on observer´s subjective judgment. It has been proved to be an objective and repeatable measurement, which is also non-invasive, quick and easy to perform for both patients and observer.

Preoperatively it can help predict photodynamic in cataract surgery. Adjusting phaco parameters based on objective lens densitometry is a promising way to improve overall efficiency of the surgery and leads to customizing the cataract surgery.

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KORELACIJA DOBNO POVEZANE GUSTOĆE KATARAKTE OCJENJENE POMOĆU SCHEIMPFLUG SUSTAVA SNIMANJA SA VIZUALNOM FUNKCIJOM I ENERGIJOM FAKOEMULZIFIKACIJE

S A Ž E T A K

Svrha ovoga rada bila je istražiti odnos između dobno povezane gustoće leće i najbolje ispravljene vidne oštrine (BCVA) te utjecaja gustoće katarakte procjenjene 3D denzitometrije leće pomoću Pentacam Nucleus Grading System (PNS) na fakodinamici (fako-vrijeme i fako-energija). Da bi se postigla svrha rada, evaluirana je gustoća katarakte povezane s dobi 55 pacijenata. Rezultati su pokazali negativnu linearnu korelaciju između gustoće leće i BCVA te pozitivnu korelaciju između gustoće i ukupne raspršene fako-energije. Katarakta određena pomoću PNS negativno korelira s vizualnom funkcijom. Pozitivna korelacija je nađena između gustoće leće i vremena i energije fakoemulzifikacije.