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# Relationship between lens density measurements by Pentacam Scheimpflug imaging and torsional phacoemulsification parameters

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## Pentacam Scheimpflug 成像测量晶状体密度与 torsional 超声乳化参数间的关系

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**摘要**

**目的**:评价运用 Pentacam Scheimpflug 成像测量晶状体核密度与 torsinal 超声乳化动力学参数(如:运用于老年核性白内障患者的超声能量水平、液体留存时间及液体量)间的关系。

**方法**:此研究为前瞻性双盲研究。瞳孔扩大后运用 Pentacam Scheimpflug 成像进行测量。白内障的等级由 pentacam 核密度测定法[pentacam nucleus densitometry, PND;又名 Pentacam 核分段(Pentacam nucleus staging, PNS)软件]自主分为 1 到 5 个等级。超声乳化术后,自动在 Infiniti Ozil IP 超声乳化系统监视器上计算并显示总超声(U/S)时间、累计耗散能、Torsional U/S 时间以及估算液体的使用情况。组间差异运用单因素方差分析(ANOVA)进行评定,多组分析运用 Tamhane 测试法,PND 测量的晶状体密度与 torsinal 超声乳化动力学参数间的关系运用 Spearman 相关分析进行评定。界定 $P<0.05$ 时具有统计学意义。

**结果**:此项研究包括 125 例患者(125 眼),平均年龄为 69.7±9.4 岁(范围:48~88 岁),其中 61 例男性、64 例女性。U/S 总时间、torsional U/S 时间、CDE 及估算液体使用情况的范围分别为 0.70~158.9s, 0.70~158.5s, 0.11~42.65 和 21~98mL. PND 组间数据有统计学差异。评估超声乳化动力学参数与 PND 数据间关系后得出 PND 数据与总超声时间($r=0.767$; $P<0.01$)、torsional 超声时间($r=0.767$; $P<0.01$)、CDE($r=0.758$; $P<0.01$)及液体使用量($r=0.602$; $P<0.01$)均有显著相关性。

**结论**:白内障手术前运用 PND 评分法获得核密度的客观程度可为超声乳化术中的参数提供可靠的预见性。因此,对每一位患者进行每一单项超声乳化参数的评估,有助于降低超声乳化能量的使用量,减少内皮细胞丢失和类固醇的使用,加速视力的恢复。

**关键词**:torsional 超声乳化;pentacam;沙氏成像;晶状体密度测定

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## Abstract

• AIM: To evaluate the relationship between the density values of the lens nucleus measured using Pentacam Scheimpflug imaging and torsional phacoemulsification dynamics such as the level of ultrasound energy, as well as the duration and amount of fluid used in patients with age-related nuclear cataract.

• METHODS: This was a prospective observer-masked study. Pentacam Scheimpflug imaging was performed following pupil dilation. The cataracts were automatically graded from 1 to 5 using pentacam nucleus densitometry (PND), also known as Pentacam nucleus staging (PNS) software by the same observer. After phacoemulsification, total Ultrasound (U/S) time, Cumulative dissipated energy (CDE), Torsional U/S time, and Estimated fluid use were automatically calculated and displayed on the monitor of Infiniti OZiL IP phacoemulsification system. One-way analysis of variance (ANOVA) was used to assess differences between groups. The Tamhane test was used for multiple group analysis. Spearman correlation analysis was used to assess the relationship between lens density measured by PND and the dynamics of torsional phacoemulsification. $P<0.05$ was considered statistically significant.

• RESULTS: In the present study, 125 eyes from 125 patients were evaluated. Mean age was 69.7 ± 9.4y (range: 48-88y), and 61 men and 64 women were included. The highest and lowest values of U/S total time, torsional U/S time, CDE, and Estimated fluid use were 0.70-158.90s, 0.70-158.50s, 0.11-42.65, and 21-98 mL in groups, respectively. Significant differences were found among PND groups. When the relationship between phacoemulsification dynamics and PND values were evaluated, there were significant correlations between PND value and total ultrasound time ($r=0.767$; $P<$

0.01), torsional ultrasound time ($r$=0.767; $P$<0.01), CDE ($r$=0.758; $P$<0.01), and amount of fluid used ($r$=0.602; $P$<0.01).

• CONCLUSION: An objective degree of nucleus density obtained by PND scoring before cataract surgery may allow antecedent determination of intraoperative phacoemulsification parameters. Thus, individualized phacoemulsification parameters should be developed for each patient. This will lead to the use of a smaller amount of phacoemulsification energy, resulting in decreased in endothelial cell loss, quicker and better visual healing, and less steroid use.

• KEYWORDS: torsional phacoemulsification; pentacam; scheimpflug imaging; lens densitometry
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## INTRODUCTION

The quantitative detection of degree of cataract density is an indispensable component of epidemiological and clinical studies on cataract[1]. Grading the density of cataract is of importance when it comes to identification of the potential risk factors of cataract development, documentation of cataract, pharmaceutical research on cataract treatment, and preoperative prediction of phacoemulsification surgery dynamics.

Clinically, the approaches used to grade density of cataract are classified into subjective and objective methods[2,3]. Subjective methods include the Lens Opacities Classification System version III (LOCS III), Wisconsin Cataract Grading System, Oxford Clinical Cataract Classification and Grading System, and Laser Slit Lamp Assessment[2-5]. LOCS III has gained wide acceptance among these classifications. In this grading system, the degree of cataract is determined through comparison to a standardized set of photographs under biomicroscopy[4]. In several studies, it has been shown that LOCS III is highly reproducible[4,5]. However, it is also associated with reliability issues due to differences in the assessment caused by intra-observer and inter-observer variations, as in all subjective grading systems[6,7]. The ideal grading system for cataract would be both reproducible and objective.

Concerns regarding LOCS III promote attempts to develop objective methods such as Scheimpflug-based photography and slit imaging. The Topcon SL-45, Zeiss Scheimpflug video camera, and Nidek EAS-1000 have been used in clinical practice[8-12]. Currently, Scheimpflug-based Pentacam camera system (Oculus, Wetzlar, Germany) has gained popularity. The Pentacam Scheimpflug imaging system is an easy, rapid, and objective grading system with a rapid learning curve and no ocular contact[7]. This system provides three-dimensional images of anterior ocular segment by capturing images in less than 2 seconds. The images captured are converted to numeric values by the specialized software in the system; therefore, several parameters for the anterior chamber, cornea, and lens can be assessed[7-9]. Measurement of density of the lens nucleus using this system is highly reproducible[6,10,11,13]. This high reproducibility is not only true for intra-observer variation, but also for inter-observer variation[11,13]. The objective degree of nucleus density obtained by Pentacam nucleus densitometry scoring before cataract surgery may allow antecedent determination of intraoperative phacoemulsification parameters.

The aim of the present study was to evaluate the relationship between the density values of the lens nucleus measured using Pentacam Scheimpflug imaging and torsional phacoemulsification dynamics such as the level of ultrasound energy, as well as the duration and amount of fluid used in patients with age-related nuclear cataract.

## SUBJECTS AND METHODS

This prospective observer-masked study was conducted at Kayseri Training and Research Hospital between March and June 2012. It was carried out in accordance with the Helsinki Declaration and approved by the hospital's Institutional Review Board. All patients gave written informed consent before participation.

The study included 125 eyes from 125 patients. Exclusion criteria were previous ocular trauma or intraocular surgery, pseudoexfoliation syndrome, preoperative pupillary width less than 6 mm, an anterior chamber depth less than 2.4 mm centrally, and systemic disease affecting vision or disease involving the eyes (diabetic retinopathy, age-related macular degeneration, or uveitis) and white cataracts. All patients underwent a comprehensive ophthalmologic examination including visual acuity assessment, intraocular pressure measurement, biomicroscopy, and dilated fundus examination. Before Pentacam Scheimpflug imaging, pupils were dilated using 2% tropicamide, 2.5% phenylephrine, and 1% cyclopentolate. Pentacam Scheimpflug imaging was performed by an experienced technician. The density of the lens nucleus was automatically graded between 0 and 5 by the device using Pentacam Nucleus Staging (PNS) software.

All surgeries were performed under topical anesthesia by the same experienced surgeon (S. D.). Phacoemulsification was performed with the quick chop technique using an Infiniti® OZiL Intellegent Phaco (IP) system (Alcon Laboratories, Fort Worth, TX, USA) and the 0.9 mm mini-flared 45° Kelman Aspiration Bypass system (ABS) phaco tip. Torsional phacoemulsification settings for the quick chop technique were as follows: ultrasound power, 85% at continuous linear mode; vacuum limit, 350 mm Hg linear; aspiration flow rate, 32 mL/min linear; dynamic rise, +2 (IP) mode; and bottle height, 95 cm. All clear corneal incisions were made with 2.2 mm keratome. Viscoat (Alcon Laboratories, Fort Worth, TX, USA) (Sodium hyaluronate 3.0% - Chondroitin sulphate 4.0%) was used to reform and stabilize AC and protect corneal endothelium. A 5.0-5.5 mm continue curvilinear capsulorhexis was made using a ultrata capsulorhexis forceps

**Table 1 Comparison of intraoperative parameters in Pentacam nucleus staging (PNS) groups**

| Variables | Pentacam nucleus staging (PNS) groups | | | | |
|---|---|---|---|---|---|
| | 1(*n*=29) | 2(*n*=32) | 3(*n*=31) | 4(*n*=17) | 5(*n*=16) |
| Total Ultrasound time | 23.62±12.28[a] | 38.94±14.78[a] | 48.51±17.56[a] | 79.88±15.87[a] | 84.16±31.68[a] |
| Torsional Ultrasound time | 23.61±12.28[a] | 38.86±14.80[a] | 48.40±17.39[a] | 79.67±15.74[a] | 83.96±31.66[a] |
| Cumulative dissipated energy (CDE) | 4.62±2.87[a] | 8.25±3.88[a] | 10.91±4.91[a] | 19.58±5.72[a] | 21.24±9.80[a] |
| Estimated fluid use | 38.66±8.68[a] | 48.69±10.54[a] | 48.58±10.97[a] | 59.29±11.70[a] | 65.69±14.58[a] |

Values are expressed as mean±SD. [a]statistically significant differences.

(Katena products, Inc, New Jersey, USA). Cortex aspiration was performed using a coaxial irrigation/aspiration tip. A hydrophobic acrylic intraocular lens (AcrySof SA60AT, Alcon Laboratories, Fort Worth, TX, USA)) was inserted into the capsular bag with same injector system (Monarch III-D Catridge, Alcon Laboratories). Sodium hyaluronate 1.0% (Provisc, Alcon Laboratories, Fort Worth, TX, USA) was used for intraocular implantation of the lens. Sodium hyaluronate 1% (Provisc, Alcon Laboratories, Fort Worth, TX, USA) was removed from AC and capsular bag using coaxial I/A system. Following surgery, total ultrasound time, torsional ultrasound time, cumulative dissipated energy (CDE), and amount of fluid used-which were automatically calculated for each patient by the Alcon-Infiniti device-were obtained from the device.

**Statistical Analysis** Were performed by using SPSS for Windows version 16.0 (SPSS Inc, Chicago, IL, USA). Normality was tested using the Shapiro-Wilk test. One-way analysis of variance (ANOVA) was used to assess differences between groups. The Tamhane test was used for multiple group analysis. Data were expressed as mean ± standard deviation. Spearman correlation analysis was used to assess the relationship between lens density measured by Pentacam nucleus densitometry (PND) and the dynamics of torsional phacoemulsification. $P<0.05$ was considered statistically significant.

## RESULTS

In the present study, 125 eyes from 125 patients were evaluated. Mean age was 69.7±9.4y (range: 48-88y), and 61 men and 64 women were included. Table 1 presents the PND measurement groups and total ultrasound time, torsional ultrasound time, CDE, and amount of fluid used. Significant differences were found among groups. When the relationship between phacoemulsification dynamics and PND values were evaluated, there were significant correlations between PND value and total ultrasound time ($r=0.767$; $P<0.01$; Figure 1), torsional ultrasound time ($r=0.767$; $P<0.01$; Figure 2), CDE ($r=0.758$; $P<0.01$; Figure 3), and amount of fluid used ($r=0.602$; $P<0.01$; Figure 4).

We stratified patients according to PND scores (graded from 1 to 5) into three groups as follows: patients with PND scores of 1 (mild cases); those with PND scores of 2 or 3 (moderate cases); and those with PND score of 4 or 5 (severe cases). It was found that patients with a PND score of 1 significantly differed from patients in the other PND groups, while there was no significant difference between patients with PND scores of 2 or 3 and those with PND scores of 4 or 5.

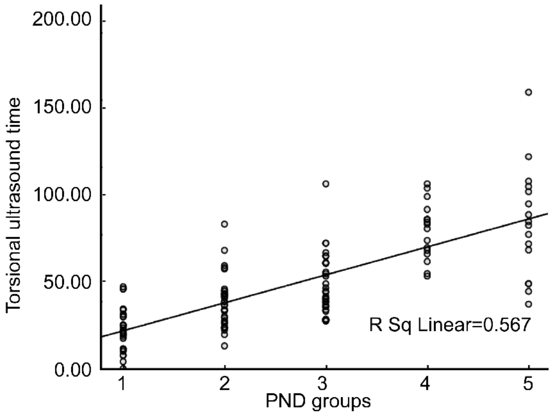


**Figure 1 Relationship between total U/S time and Pentacam lens nucleus densitometry (PND) groups.**

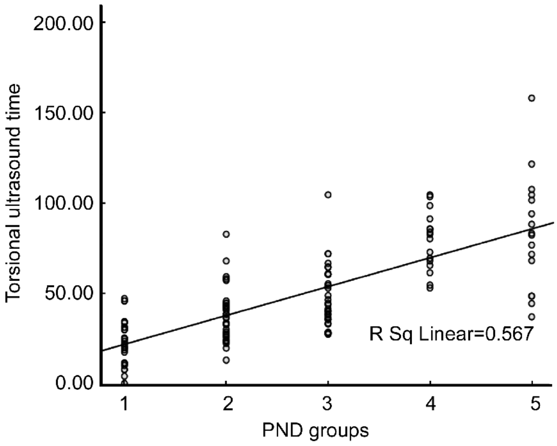


**Figure 2 Relationship between Torsional U/S time and Pentacam lens nucleus densitometry (PND) groups.**

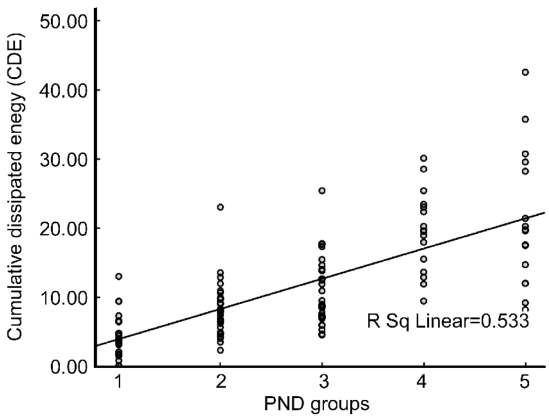


**Figure 3 Relationship between CDE and Pentacam lens nucleus densitometry (PND) groups.**

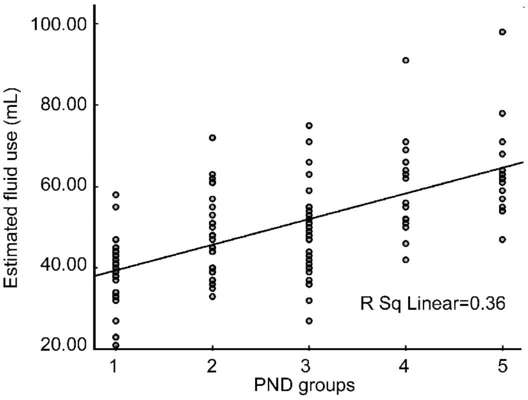


**Figure 4　Relationship between estimated fluid use and Pentacam lens nucleus densitometry (PND) groups.**

## DISCUSSION

In the present study, we evaluated the relationship between density of the lens nucleus estimated using the PND system and different phacoemulsification parameters. A significant, strong correlation was detected between PND score and total ultrasound time, torsional ultrasound time, CDE, and amount of fluid used. In a study using both LOCS III and a Pentacam Scheimpflug camera system to determine the degree of density of lens nucleus, Kim *et al*[10] evaluated several parameters using same torsional phacoemulsification system. The authors found a strong correlation between density of the lens nucleus and total ultrasound time, torsional ultrasound time, and CDE. Although their findings are consistent with our results, they reported that the amount of fluid did not correlate with PND scoring[10]. A similar finding was detected in another study using the LOCS III grading system[11]. In contrast, another study, as well as our own, detected a positive correlation between amount of fluid used and PND scoring[14]. Kim *et al*[10] published other important findings that PND scoring has a stronger positive correlation with CDE when compared to LOCS III and PND measurements are superior to LOCS III in the detection of lens nucleus status. In recent study, Gupta *et al*[15] reported that both systems had a linear correlation with total U/S power, CDE and fluid use; however, PND grading system had a stronger correlation with these phacoemulsification parameters.

There are three major criteria in the identification of cataract severity and the need for surgery[16]. These include degree of lens opacity, acuity of vision, and alteration in quality of life. The incidence of nuclear cataract increases with advancing age. In nuclear cataract, the mechanisms underlying the worsening in vision are scattering of light and opacity in the lens nucleus following refractive changes in lens material[6,17]. There are many systems that detect and grade nuclear opacities. It is impossible to eliminate observer-related errors in LOCS III and other subjective methods widely used for this purpose. However, the Pentacam Scheimpflug camera system is an objective system that provides information about the density of the lens nucleus[7,8,18]. This system enables the anterior and posterior cortical regions of the lens to be differentiated[13,19].

In cataract surgery, most of the phacoemulsification energy used is expended on the removal of the lens nucleus[12,14,18]. Thus, detection of the true density of the lens and preoperative identification of phacoemulsification parameters can provide surgical advantages. However, most cataract surgeries are initiated as a result of routinely used parameters and minor modifications are carried out during surgery. This results in the use of excessive phacoemulsification energy in patients with lower lens nucleus density, and causes prolongation of phacoemulsification time, total ultrasound time, and increased CDE due to insufficient power in those with high lens nucleus density. As mentioned previously, we can classify patients into three groups according to PNS software before cataract surgery and provide individualized nomogram phacoemulsification parameters for PNS value in each patient. A similar correlation was detected in another study using same phacoemulsification system as ours. In addition, Chikamoto *et al*[20] found similar findings to ours, using a different phacoemulsification system and different cataract analysis device based on Scheimpflug imaging.

In a study in which patients who underwent standard cataract surgery were compared to those who underwent cataract surgery with individualized phacoemulsification parameters according to nucleus density measured by PND scoring, Nixon[14] reported that there was a significant decrease in effective phacoemulsification time, amount of fluid used, and total phacoemulsification time. A significant difference was found between patients with a PND score of 1 and those with PND scores of 4 or 5 in the group underwent surgery with individualized phacoemulsification parameters. Effective phacoemulsification time, amount of fluid used, and total phacoemulsification time were increased by higher density of lens nucleus. These findings are in accordance with our results. In our study, CDE was evaluated in addition to the above-mentioned parameters, showing a positive correlation.

Pentacam nucleus staging software has some limitations arising from not only distortion at refractive surface but also disability of sampling technology due to insufficient mydriasis, presence of lens tilted and white cataracts[18,21].

In conclusion, the objectivity of PND scoring means that it is likely to be an appropriate monitoring system in epidemiological studies investigating the development of nuclear cataract and the assessment of drugs preventing or inducing cataract. In addition, an objective degree of nucleus density obtained by PND scoring before cataract surgery may allow antecedent determination of intraoperative phacoemulsification parameters. Thus, individualized phacoemulsification parameters should be developed for each patient. This will lead to the use of a smaller amount of phacoemulsification energy, resulting in decreased in endothelial cell loss, quicker and better visual healing, and less steroid use[12,22,23].

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