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The importance of corneal biomechanical properties in ocular hypertension and glaucoma

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Abstract:

Purpose: The aim of this study is to determine the role of corneal biomechanics, measured by Ocular Response Analyzer(ORA), in ocular hypertension and glaucoma.

Material and methods: The study included 107 eyes that were divided into 3 groups based on the intraocular pressure(IOP) and the presesence or absence of glaucomatous damage: the first group included 52 glaucomatous eyes, the second one 33 eyes with ocular hypertension(OH) and the third group 22 normal controls.

Results: The mean corneal hysteresis(CH) and corneal resistance factor(CRF) were lower in the glaucoma and OH groups than in normal individuals. A negative correlation between CH and Goldmann IOP was found in all three groups: glaucoma group (r=-0,25, p<0,001), OH group (r=-0,26, p<0,003) and normal group (r=-0,18, p<0,04).

Conclusions: Corneal biomechanical properties are altered in glaucoma and ocular hypertension patients showing that a low corneal hysteresis in a patient with raised IOP could indicate a higher risk for developing glaucomatous damage.

Key words: corneal hysteresis, biomechanics, glaucoma, ocular hypertension

1. Introduction:

Raised intraocular pressure represents the main risk factor for glaucoma and this patients need to be monitored precisely in order to determine which of them have a higher risk of develioping the disease (1). Glaucoma is an optic neuropathy that consists of gradual loss of ganglion cells and their axons resulting in visual field damage (2) (3) (4). Ocular hipertension consits of raised values of the IOP, in the absence of glaucomatous optic neuropathy (4).

Intraocular pressure mesurements can be influenced by many factors including central corneal thickness as well as corneal viscosity, rigidity and corneal biomechanical properties (5). Regardless of the other factors involved, the IOP is the only risk factor that can be modified with treatment and this is why the IOP mesurement captured ophthalmologists attention for many years (6).

The structure of the cornea can be described as having two types of properties: structural and biomechanical (7). Structural properties are represented by topography and central corneal thickness, while biomechanical properties are illustrated trough corneal hysteresis and corneal resistance factor. Geometrical properties have been studied further than the biomechanical ones, but recently, more and more studies reflect the involvement of the corneal biomechanics in the measurement of intraocular pressure and evaluation, diagnosis and progression of glaucoma (7) (8) (9) (7) (10) (8) (9) (11) (12) (13) (14) (15).

Ocular Response Analyzer(Reichert, Buffalo, New York, USA) is a device initialy designead as a non invasive method of measuring the IOP, but the machine is capable of more than that, this being one of the few devices that measure in vivo corneal bimechanics (16) (17).

2. Material and methods:

107 eyes of the 138 examined fufilled the inclusion criteria and were included into the study being devided into 3 groups: 52 eyes in the first group, 33 eyes in the second group and 22 in the third group. For the first group the inclusion criteria constituded of primary open angle glaucoma patients with glaucomatous optic neuropathy (asymmetry of the excavations between the two eyes of 0,2 or more, retinal nerve fiber layer(RNFL) defects, decreased RNFL, peripapillary hemorrhages) and visual field damage (low MD or Glaucoma Hemifield Test: Outside normal Limits). For the second group patients with high IOP and without any sign of optic neuropathy or visal field damage. The last group consisted of eyes with no history of ocular disorder, normal IOP measurements, symmetric excavations cup/disc ratio 0,4 or less, and normal retinal nerve fiber layer, and abnormal visual field test.

All patients underwent a complete examination that included best corrected visual acuity, anterior pole examination with the slit lamp, IOP measurements (Goldmann applanotonometer), gonioscopic examination (Goldmann lens), ultrasound pachimetry (Alcon® OcuScan® RxP Ophthalmic Ultrasound System), visual field analyses (Humphrey Field Analyzer II - Carl Zeiss Meditec Inc, Dublin, California) strategy 24-4 and fundus examination.

The ORA was used in order to determine in vivo corneal biomechanical properties. We determined 3 measurements on each eye with waveform score higher than 7 and we used the best measurement in the study. ORA functions similar to non contact tonometers: the device generates an air pulse that indents the cornea centrally determining it to move inward and than outward as it comes back to the initial shape (18) (19). ORA incorporates an infrared electrooptic system that reads the information from the central 3mm of the cornea. Using mathematichal formulas the device generates the report, including corneal biomechanical properties (10) (20).

The report that ORA generates consists of 4 parameters: IOPg (a measured intraocular pressure that corresponds to Goldman IOP), IOPcc (a corrected IOP that takes into consideration corneal biomechanics), CH (corneal hysteresis) and CRF (corneal resistance factor) (21) (11) (17) (22) (16).

IOPcc coresponds to an IOP measurement that thakes into consideration corneal properties and is supposed to be more accurate than IOPg (23) (11) (10) (22) The apparatus measures the two applanation pressures and the atributes the values to the algorithm within the machine reevaluating the IOP on the corneal biomechanical properties (24) (12) (10) (21) (18). IOP g represent an IOP estimation that is similar to the value provided by the Goldmann applanotonometer (25) (11) (10) (22). The correlation between IOPg and IOP measured by Goldmann applanotonometer is supported by studies such as the one conducted by Ehrlich et al (25).

CH is calculated by the difference between the two IOP measured by ORA (14) (15). It does not reveal an intrinsec property of the cornea, but it is relevant for corneal viscoelasticity and its ability to absorb and disipate energy (26) (16) (21) (11). Hysteresis is influenced by corneal collagenic structure, its degree of hidratation and central corneal thickness (5). Even if it was thought that CH varies with IOP Kida et al reveal in their study that even if IOP varies, CH does not modify considerably in the same eye (17).

CRF is dependent on the CH and is an indicator of the global resistance of the cornea (12) (16) (27)
Our statistical analysis consisted of descriptive analysis, frequency tests, means and linear regression.

3. Results:

Out of the 107 eyes included in the study, 67,33% were hipermetropic and 32,67% myopic. In both OH and glaucoma groups, IOP was higher than in normal individuals regardless of the measuring device. The mean Goldman IOP was 19,01 ± 4,2587 mmHg in the first group, 18,90 ± 2,7851 mmHg in the second group and 15.04 ± 1,2141 mmHg in the third group, values comparable to the ones delivered by ORA´s IOPg: 19,04 ± 5,5696 mmHg for the first group, 19,17 ± 3,2676 mmHg for the second group and 16.00 ± 2,0944 in the third group. ORA generates the IOPcc after adding into the ecuation corneal properties. In our study IOP values raise for the OH and glaucoma groups, but do not varies in the normal group. Mean IOPcc was 20,69 ± 6,1933 mmHg for the glaucoma group, 20,18 ± 3,2391 mmHg for the OH group and 15,06 ± 2,0838 mmHg in normal patients group.

Our study showed that CH, CRF and CCT were lower in OH than in normal individuals and in glaucoma patients even lower than in OH patients.

The mean CH in the first group was 8,88 ± 2,4353, in the second group 9,44 ± 1,3827 and in the third group 12,15 ± 1,1835. In the first group the mean CRF was 10,17 ± 2,1822, in the second group 10,70 ± 1,4949 and in the third group 11,66 ± 1,2230. The mean CCT was 523,21 ± 30,9723 microns in glaucoma patients, 539,42 ± 24,5832 microne in ocular hypertension group and 548,77 ± 24,7970 in normal patients.

We used linear regression in order to investigate the relationship between corneal biomechanics and other parameters used to monitor glaucoma and OH patients.

We found a statistically significant correlation between Goldmann IOP and ORA´s IOPcc in all three groups: in the first group($r=0,79$, $p<0,001$), in the second group($r=0,39$, $p<0,001$) and in the third group($r=0,37$, $p<0,002$). This correlation shows once again the involvement of corneal properties in the measurement of the IOP. If this correlation would have been higher, it woud have shown that Goldmann IOP is similar to ORAs IOPcc, so there are no factors that would have influenced the IOP measurements.

Our study revealed a positive corrrelation between CH and CCT in glaucona group($r=0,33$, $p<0,001$), OH group($r=0,04$, $p<0,35$) and normal individuals ($r=0,22$, $p<0,04$), but statistically significant only in the glaucoma and normal groups.

A statistically significant negative correlation between CH and Goldmann IOP was found in glaucoma group ($r=-0,25$, $p<0,001$), OH group ($r=-0,26$, $p<0,003$) and normal group ($r=-0,18$, $p<0,04$).

4. Discussions:

In recent times, authors have shown a bigger interest in the involvement of corneal properties in the management of glaucoma and ocular hypertension patients (7) (16) (21) (8) (9) (11) (12) (13) (15) (14).

Our study demonstrates that even if Goldmann IOP has minor differences between glaucoma and OH groups, in glaucoma the IOP being higher, after adjusting for corneal biomechanics, IOPcc has similar values for both groups suggesting that OH patients have higher risk to develop glaucomatous damage than we initially considered.

It is already known that CCT is an independent risk factor for glaucoma, but there are studies that show a separate implication of the CH in glaucoma progression (1) (8) (28). Even if in our study CCT was lower in glaucoma group than in OH and normal individuals, CCT was not the only factor that made the Goldmann IOP lower than the ORA´s corrected IOP, CH and CRF being also lower in OH patients than in normal individuals, and in glaucoma patients are lower than in the other two group. This suggests an underestimation of Goldmann ´s IOP measurement.

As well as other studies show, our study revealed a negative corrrelation between CH and IOP in all three groups, so a low CH is associated to a high IOP and a low IOP is associated to a high CH (7) (16) (21) (8) (9) (11) (12) (13) (15) (14). Many studies suggest that central corneal thickness is not the only factor that influence IOP mesurements and that ORA´s IOPcc eliminates the corneal influence over the evaluation of intraocular pressure (29) (28) (30) (24) (31).

5. Conclusions:

Corneal biomecanical properties could help us differentiatiate OH from glaucoma, to detect which patients have a higher risk on developing the disease or in already diagnosed patients, which of them are at risk of rapid progression.

Knowing the importance of an accurate IOP measurement in glaucoma and OH patients, we can understand the importance of corneal biomechanics in IOP measurement.

Further studies are nedded in order to prove that CH could have a bigger role in glaucoma follow up.

6. Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

7. Acknowledgments

All authors have equal contribution and equal participation in the paper.

8. References

1. **Michael A. Kass, MD; Dale K. Heuer, MD; Eve J. Higginbotham, MD.** „The Ocular Hypertension Treatment Study”. s.l. : Archives Ophthalmology, 2002. 120(6):701-713. doi:10.1001/archopht.120.6.701.

2. **Yu Jeong KimMin Ho KangHee Yoon ChoHan Woong LimMincheol Seong.** „Comparative study of macular ganglion cell complex thickness measured by spectral-domain optical coherence tomography in healthy eyes, eyes with preperimetric glaucoma, and eyes with early glaucoma". s.l. : Japanese Journal of Ophthalmology, 2014. doi: 10.1007/s10384-014-0315-7.

3. **Bruno Lambroso, Marco Rispoli.** „Practical Retinal OCT". s.l. : The Health Sciences Publishers, 2015. 978-93-5152-532-5.

4. **American Academy of Ophthalmology.** „Glaucoma". s.l. : American Academy of Ophthalmology, 2011-2012. 978-1615252374.

5. **Dorin Chiseliță.** „Glaucomul Primitiv cu Unghi Deschis". s.l. : Editura Gr. T. Popa UMF Iasi, 2014. 978-606-544-267-2.

6. **Anne L Coleman and Gergana Kodjebacheva.** „Risk Factors for Glaucoma Needing More Attention. s.l. : The Open Ophthalmology Journal", 2009. doi: 10.2174/1874364100903010038.

7. **NaimTerai , Frederik Raiskup , MichaelHaustein ,Lutz Pillunat , Eberhard Spoerl.** „Identification of biomechanical properties of the cornea: the ocular response analyzer". s.l. : Current Eye Research, 2012. Vol. 37 issue7. doi: 10.3109/02713683.2012.669007.

8. **Dana Dascalescu, Catalina Corbu, Miruna Cristea, Catalina Ionescu, Raluca Iancu, Speranta Schmitzer and Liliana Voinea** „Corneal biomechanics involvement in primary open angle glaucoma" s.l. : Proceedings on the Romanian Academy B series, 2015. Proc. Rom. Acad., Series B, 2015, Supplement 1, p. 55-57.

9. **Dana Dascalescu, , Catalina Corbu, Mihaela Constantin, Miruna Cristea, ; Catalina Ionescu, ; Miruna Cioboata, Liliana Voinea.** „Correlations between Corneal Biomechanics and Glaucoma Severity in Patients with Primary Open Angle Glaucoma" s.l. : MAEDICA – a Journal of Clinical Medicine, 2015. 1841-9038.

10. **Sushmita Kaushik and Surinder Singh Pandav.** „Ocular response analyze"r. s.l. : Journal of courent glaucoma practice, 2012. . doi: 10.5005/jp-journals-10008-1103.

11. **Sullivan-Mee M, Billingsley SC, Patel AD, Halverson KD, Alldredge BR, Qualls C.** Ocular Response Analyzer in subjects with and without glaucoma. s.l. : Optometry & Vision Science, 2008. DOI: 10.1097/OPX.0b013e3181784673.

12. **David A. Luce.** „Determining in vivo biomechanical properties ofthe cornea with an ocular response analyzer". s.l. : Journal of Cataract and Refractive Surgery, 2004. DOI: http://dx.doi.org/10.1016/j.jcrs.2004.10.044.

13. **Andrew Lam, Davie Chen Roger Chiu, Wan-Sang Chui.** „Comparison of IOP Measurements Between ORA and GAT in Normal Chinese". s.l. : Optometry & Vision Science, 2007. doi: 10.1097/OPX.0b013e3181559db2.

14. **Susanne Christiane Goebels, Berthold Seitz & Achim Langenbucher .** „Precision of ocular response analyzer". s.l. : Current eye research, 2012. http://dx.doi.org/10.3109/02713683.2012.660592.

15. **D Pensyl, M Sullivan-Mee, M Torres-Monte, K Halverson and C Qualls.** „Combining corneal hysteresis with central corneal thickness and intraocular pressure for glaucoma risk assessment". s.l. : Eye , 2012. doi:10.1038/eye.2012.164.

16. **Sushmita Kaushik,Surinder Singh Pandav.** „Ocular Response Analyzer". s.l. : Journal of Current Glaucoma Practice, 2012. doi: 10.5005/jp-journals-10008-1103.

17. **Teruyo Kida; John H. K. Liu; Robert N. Weinreb.** „Effect of 24-Hour Corneal Biomechanical Changes on Intraocular Pressure Measurement". s.l. : Investigative Ophthalmology & Visual Science October 2006,, 2006. doi:10.1167/iovs.06-0507.

18. **Ioana Catalina Ionescu, Catalina Gabriela Corbu, Cristina Tanase, Christian JonescuCuypers, Cristina Nicula, Dana Dascalescu, Miruna Cristea, Liliana-Mary Voinea.** „Inflammatory Biomarkers Profile as Microenvironmental Expression in Keratoconus". s.l. : Disease Markers Hindawi Publishing Corporation, 2016. http://dx.doi.org/10.1155/2016/1243819..

19. **A E Davidson, S Hayes, A J Hardcastle and S J Tuft.** „The pathogenesis of keratoconus". s.l. : Eye, 2013. doi:10.1038/eye.2013.278..

20. **Michèle Detry-Morel, Jacques Jamart, Frédéric Hautenauven, Sayeh Pourjavan.** „Comparison of the corneal biomechanical properties with the Ocular Response Analyzer® (ORA) in African and Caucasian normal subjects and patients with glaucoma". s.l. : Acta Ophthalmologica, 2011. DOI: 10.1111/j.1755-3768.2011.02274.x.

21. **Jose M Martinez-de-la-Casa, Julian Garcia-Feijoo, Ana Fernandez-Vidal, Carmen Mendez-Hernandez, Julian Garcia-Sanchez.** „Ocular Response Analyzer versus Goldmann Applanation Tonometry for Intraocular Pressure Measurements". s.l. : Investigative Ophthalmology and Visual Science, 2006. Vol. 47. 410-4414. doi:10.1167/iovs.06-0158.

22. **Sushmita Kaushik, Surinder Singh Pandav, Anupam Banger, Kanika Aggarwal, Amod Gupta.** „Relationship between corneal biomechanical properties, central corneal thickness, and intraocular pressure across the spectrum of glaucoma". s.l. : American Journal of Ophthalmology, 2012. http://dx.doi.org/10.1016/j.ajo.2011.10.032.

23. **Medeiros, Felipe A. și MD, Robert N. Weinreb.** „Evaluation of the influence of corneal biomechanical properties on intraocular pressure measurements using the ocular response analyzer". s.l. : Journal of Glaucoma, 2006. doi: 10.1097/01.ijg.0000212268.42606.97..

24. **Corbu, Ctalina.** „Keartoconus - diagnostic și tratament". s.l. : Editura Universitara, "Carol Davila", Bucuresti, 2014. 978-973-708-754-6..

25. **JR Ehrlich, S Haseltine, M Shimmyo, NM Radcliffe.** „Evaluation of agreement between intraocular pressure measurements using Goldmann applanation tonometry and Goldmann correlated intraocular pressure by Reichert's ocular response analyser" . s.l. : Eye, 2010. DOI: 10.1038/eye.2010.83.

26. **Dascalescu Dana, Constantin Mihaela, Iancu Raluca, Cristea Miruna, Ionescu Catalina, Cioboata Miruna, Speranta Schmitzer, Corbu Catalina.** „Corneal hysteresis and primary open angle glaucoma". s.l. : Romanian Journal of Ophthalmolog, 2015. Volume 59, Issue 4, October-December 2015. pp:252-254..

27. **Paul Foster.** „Intraocular pressure and corneal biomechanics in an adult british population: the EPIC Norfolk eye study". s.l. : Investigative Ophthalmology & Visual Science, 2011. doi:10.1167/iovs.11-7853..

28. **Nathan M. Radcliffe.** „Hysteresis, a powerful tool in glaucoma care". s.l. : Review of Ophthalmology, 2014. 93729647.

29. **C. Starck Johnson; Shahzad I. Mian; Sayoko Moroi; David Epstein; Joseph Izatt; Natalie A. Afshari.** „Role of corneal elasticity in damping of intraocular pressure". s.l. : Investigative Ophthalmology & Visual Science, 2007. DOI: 10.1167/iovs.06-0719.

30. **Christoph Hirneiß,Marcus Kernt,Alice Yu,Aljoscha S. Neubauer,Anselm Kampik.** „Corneal biomechanics measured with the ocular response analyzer in patients with unilateral open-angle glaucoma". s.l. : Acta Ophthalmologica, 2011. DOI: 10.1111/j.1755-3768.2010.02093.x..

31. **Nery Garcia-Porta, Paulo Fernandes, Antonio Queiros, Jose Salgado-Borges, Manuel Parafita-Mato, Jose Manuel Gonzales-Meijome.** „Corneal Biomechanical Properties in Different Ocular Conditions and New Measurement Techniques". s.l. : International Scholarly Research Notices Ophthalmology, 2014. http://dx.doi.org/10.1155/2014/724546..

32. **Craig Bootea, Sally Dennisa, Yifei Huangb, Andrew J. Quantocka, Keith M. Meeka.** "Lamellar orientation in human cornea in relation to mechanical properties". s.l. : Journal of Structural Biology, 2005. DOI: 10.1016/j.jsb.2004.08.009.

33. **Dorin Chiseliță.** „Actualitati si controverse in glaucom". s.l. : Editura „Gr. T. Popa" UMF Iasi, 2014. 617.7-007.681.

34. **European Glaucoma Society.** „Terminology and guidelines for glaucoma(4th edition)". s.l. : European Glaucoma Society, 2014. 978-88-98320-05-9.

35. **Zisis Gatzioufas, Georgios Labiris,Oliver Stachs,Marine Hovakimyan,Arnulf Schnaidt,Arne Viestenz,Barbara Käsmann-Kellner,Berthold Seitz.** „Biomechanical profile of the cornea in primary congenital glaucoma". s.l. : Acta Ophthalmologica, 2012. DOI: 10.1111/j.1755-3768.2012.02519.x.

36. **Jay S. Pepose, MD, PhD, Susan K. Feigenbaum, PhD, Mujtaba A. Qazi, MD, Jeffrey P. Sanderson, MD, Cynthia J. Roberts, PhD.** „Changes in Corneal Biomechanics and Intraocular Pressure Following LASIK Using Static, Dynamic, and Noncontact Tonometry". s.l. : American Journal of Ophthalmology, 2007. DOI: http://dx.doi.org/10.1016/j.ajo.2006.09.036.

37. **Medeiros, Felipe A. și MD, Robert N. Weinreb.** „Evaluation of the influence of corneal biomechanical properties on intraocular pressure measurements using the ocular response analyzer". s.l. : Journal of Glaucoma, 2006. doi: 10.1097/01.ijg.0000212268.42606.97.