

## Intraocular Pressure Measurement in Eyes with Silicone Oil Tamponade: What We Know and Do Not Know?

Yang Zhang and Qi Zhou\*

Department of Ophthalmology, Peking Union Medical College Hospital, Peking Union Medical College, Chinese Academy of Medical Sciences, Beijing, China

\*Corresponding author: Qi Zhou, Department of Ophthalmology, Peking Union Medical College Hospital, Peking Union Medical College, 100730, Beijing, China, Tel: +86-10-69151660; Fax: +86-010-69156358; E-mail: [zqhy\\_107@126.com](mailto:zqhy_107@126.com)

Received date: June 27, 2017; Accepted date: July 14, 2017; Published date: July 17, 2017

Copyright: ©2017 Zhang Y, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

**Keywords:** Corneal biomechanical properties; Corvis ST tonometer; Goldmann applanation tonometry; Intraocular pressure; Silicone oil tamponade

### Intraocular Pressure Measurement

Intraocular pressure spike after vitrectomy and silicone oil (SO) tamponade is a common postoperative complication [1]. If it is undiagnosed or not treated in time, it would cause further damage to the optic nerve and the retina, thus obscured the efficacy and lowered the success rate of vitreoretinal surgeries. That is why IOP assessment is of paramount important in postoperative period.

Unfortunately, what the present tonometer could measure is exactly the “extra-ocular” pressure rather than the true intraocular pressure. Most tonometric techniques, like applanation, measure the pressure by monitoring corneal response to an applied mechanical force. It is based on the so-called Imbert-Fick principle, which was invented by ophthalmologists. There are many physics and engineering assumptions underlying each tonometric technique. However there are no such ideal eyes. With the advance of cornea based refractive surgery, the influences of central cornea thickness (CCT) and corneal biomechanical parameters (CBPs) on IOP measurement have been well recognized [2].

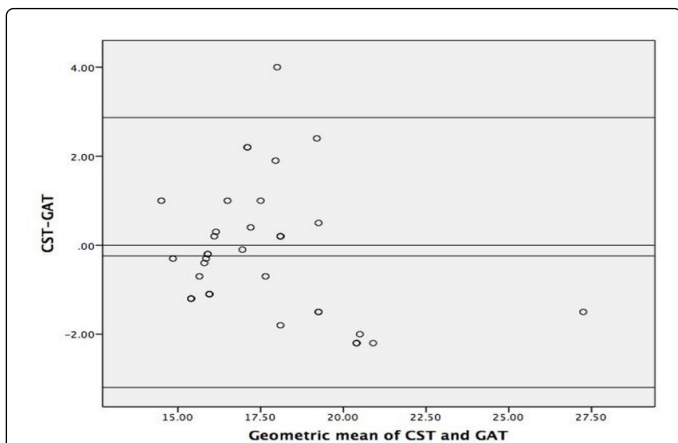
A study using an ocular response analyzer (ORA) to measure IOP of SO tamponade eyes showed that SO tamponade might affect CBPs in early postoperative period. It would lower the corneal hysteresis (CH) and increase the corneal resistance factor (CRF) [3]. Therefore it is hypothesized that SO tamponade will affect the corneal mechanics and IOP measurement by different tonometers. In our pilot study, we assessed IOP in 38 eyes following uneventful 23G pars plana vitrectomy (PPV) with SO tamponade one month after surgery, in the sequence of NCT, CST and GAT or CST, NCT and GAT. We excluded eyes that undergone combined cataract surgery with PPV and those with complications like severe postoperative inflammation, hyphema, pupillary block, hypotony (IOP<6 mmHg) and hypertony (IOP>25 mmHg). We also evaluated CST CBPs to see if these metrics could account for the differences among CST, NCT and GAT readings. From our previous study, we now know the followings [4].

1. NCT might better be avoided in SO tamponade eyes. There were statistically significant differences in IOP taken by all three devices ( $p<0.001$ ). Multiple comparison analysis demonstrated that both CST and GAT obtained significantly higher IOP readings than NCT (both  $p=0.000$ ). However, there was a good correlation on IOP measured by CST and GAT, no significant difference was found between them ( $p=0.587$ ). Bland-Altman plots (Figures 1-3) showed that postoperative IOP measured by CST was 0.24 mmHg lower than GAT

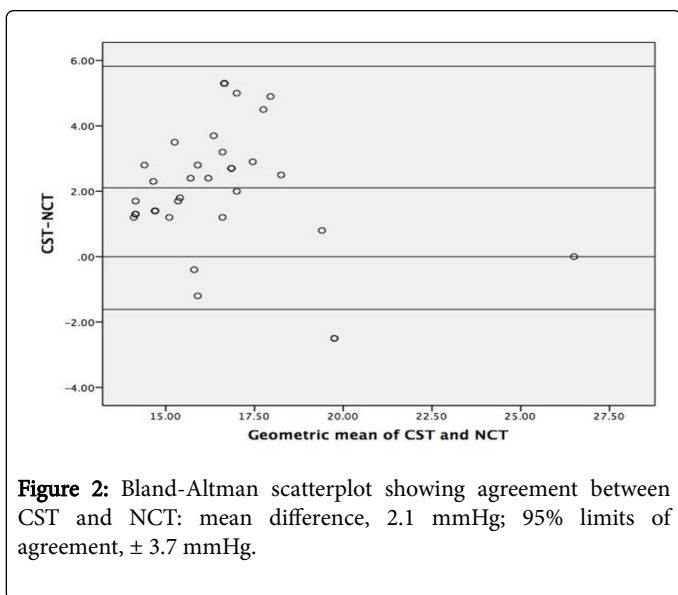
(95% limits of agreement, -3.1 to 2.6 mmHg), and 2.1 mmHg higher than NCT (95% limits of agreement, -1.6 to 5.8 mmHg), and GAT was 2.3 mmHg higher than NCT (95% limits of agreement, -1.7 to 6.3 mmHg). Compared to CST or GAT, NCT might offer a lower IOP reading. It should be noted because lower IOP measurements could lead to a delay in the detection and treatment of glaucoma.

2. GAT might not be affected by corneal biomechanical properties; at least those assessed by CST and are fit for SO tamponade eyes. The inter-tonometer differences of postoperative IOP values GAT-NCT and CST-NCT correlated significantly with the patients' age, AL, CCT and CBPs. While no significant correlation was found between the inter-tonometer differences of postoperative IOP values GAT-CST and AL, CCT and CBPs in SO tamponade eyes (Table 1), this is in agreement with healthy and glaucoma eyes [5]. The observed inter-tonometer discrepancies might be due to the differences of the corneal biomechanical properties. And CST is the only instrument taking into account of corneal biomechanical properties among the three compared tonometers.

3. The changes in corneal biomechanical properties after PPV and SO tamponade might be caused by incision of the vitrectomy and the SO tamponade as a whole. Under normal conditions, surgical incision might contingently cause some changes in the corneal viscoelastic properties as shown by studies of surgical procedures like deep sclerectomy with collagen implant and keratorefractive surgery, including laser in situ keratomileusis (LASIK) and clear corneal phacoemulsification [6-8]. Meanwhile, removing the vitreous gel and filling with SO might change the biophysical behavior of the whole globe and eventually change the corneal viscoelasticity. In our previous study, all patients received an uncomplicated 23G 3-port transconjunctival sutureless PPV; by going no scleral cautery or sutureless, the possible influence of 23G PPV on corneal biomechanics was low, especially compared to a 20-G conventional vitrectomy. In addition, in the SO tamponade eye, the correlation between NCT and both GAT and CST was not as good as that in healthy and glaucoma subjects [5]. The ORA study on SO tamponade eyes showed a different type of CBPs changes after pure PPV and PPV+SO [3]. Therefore, we deduced that the changes in corneal biomechanics were crucially influenced by SO tamponade.



**Figure 1:** Bland-Altman scatterplot showing agreement between CST and GAT: mean difference, -0.24 mmHg; 95% limits of agreement,  $\pm 2.9$  mmHg.

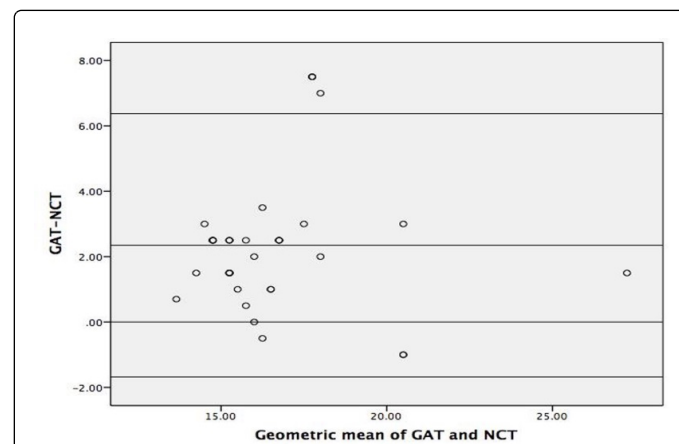


**Figure 2:** Bland-Altman scatterplot showing agreement between CST and NCT: mean difference, 2.1 mmHg; 95% limits of agreement,  $\pm 3.7$  mmHg.

There are still many unanswered questions on IOP measurement of SO tamponade eyes.

How biomechanical properties of eyes are altered after SO tamponade? The big limitation in our previous study is the lack of

control groups. Though we measured CBPs by CST, we are still not aware of their clinical relevance. Now, in the ongoing study, we set three different age and race-matched control groups, one group of healthy eyes, one group of the same preoperative eyes and one with pure PPV without any tamponade.



**Figure 3:** Bland-Altman scatterplot showing agreement between GAT and NCT: mean difference, 2.3 mmHg; 95% limits of agreement,  $\pm 4.0$  mmHg.

With these control groups, we can further confirm what we found in the previous study and validate the hypothesis about the changes of CBPs and their effects on IOP measurement after SO tamponade by different tonometers.

How are CST CBPs and ORA CBPs related? We are going to include another tonometer ORA, which is designed to improve the accuracy of IOP by using corneal biomechanical data to calculate a biomechanical adjusted estimate of IOP. We would like to see if ORA measured CBPs would affect GAT measured IOP in the same way as CST. CH measured by ORA was supposed to be an independent risk factor of glaucoma, and this has been confirmed by a randomized controlled study [9]. We will try to reveal how CST measured CBPs would affect IOP readings, and to establish an IOP correction formulae taking into account of CBPs. It is also interesting to understand the differences of IOP measurements by various tonometers. The more information we have on IOP measurement by various tonometers, the closer to the true IOP we would get. This will help to understand the changes after SO tamponade and guide in choosing an appropriate tonometer in clinic as well.

Correlation	GAT-NCT	CST-NCT	CST-GAT
AGE (year)	0.556 (0.000)	0.334 (0.041)	-0.428 (0.006)
AL (mm)	-0.529 (0.001)	-0.423 (0.008)	0.081 (0.629)
CCT (um)	-0.439 (0.006)	-0.934 (0.000)	-0.248 (0.134)
Time A1 (ms)	-0.358 (0.027)	-0.248 (0.133)	-0.047 (0.780)
Length A1 (mm)	-0.501 (0.001)	-0.494 (0.002)	0.231 (0.134)
Velocity A1 (m/s)	0.257 (0.119)	0.342 (0.036)	0.114 (0.497)
Time A2 (ms)	0.224 (0.176)	0.201 (0.227)	-0.051 (0.763)

Length A2 (mm)	-0.362 (0.025)	-0.159 (0.342)	0.077 (0.645)
Velocity A2 (m/s)	-0.298 (0.069)	0.033 (0.844)	0.404 (0.072)
Time HC (ms)	0.430 (0.007)	0.571 (0.000)	0.105 (0.532)
Def Ampl HC (mm)	0.413 (0.010)	0.571 (0.000)	-0.124 (0.458)
Peak Dist HC (mm)	0.185 (0.265)	-0.022 (0.894)	-0.252 (0.127)
Radius HC (mm)	-0.186 (0.262)	-0.570 (0.000)	-0.215 (0.195)

Time A1: Time from starting until the first-degree appplanation is reached; Length A1: Cord length of the first-degree appplanation; Velocity A1: Corneal speed during the first-degree appplanation; Time A2: Time from starting until the second-degree appplanation is reached; Length A2: Cord length of the second-degree appplanation; Velocity A2: Corneal speed during the second-degree appplanation; Time HC: Time from starting until highest concavity is reached; Def Ampl HC: Maximum amplitude at the apex of highest concavity; Peak Dist HC: Distance of the 2 knee's at highest concavity; Radius HC: Central concave curvature at highest concavity.

**Table 1:** The correlation coefficients between the differences of IOP measurements and patient/corneal characteristics.

Are the differences of IOP measurement by different tonometers solely due to corneal biomechanical changes after SO tamponade? The corneal biomechanical changes might due partly to sclerotomy incisions and partly to the mechanical stress of vitrectomy on the globe [10]. Woo and associates analyzed stress and strain characteristics of sections from different parts of whole human globes and found that the biomechanical characteristics of the anterior segment approximate that of the whole globes [11]. A normal eye is filled with vitreous gel; vitreous play a significant role in the formation of IOP. After PPV and SO tamponade, normal vitreous gel is replaced by SO, a liquid quite different from the gel. As we know, some tonometers measured IOP indirectly by monitoring corneal response to the applied mechanical force by means of light ray. Will the material filling the cavity influence the function of the device tracing the corneal responses? Furthermore, an ophthalmologist will typically decide the amount of SO based on their own experience, so there will be some discrepancy on the degree of filling fullness of SO. We are wondering whether this discrepancy will affect the CBPs, thus affecting IOP measurement as well, or maybe SO, the material itself is an independent factor for IOP measurement. We are now testing the inter tonometer differences between ORA CBPs matched SO tamponade eyes and healthy and glaucoma eyes.

4. Are there postural factors in IOP measurement in SO tamponade eyes and what is the diurnal fluctuation of IOP in SO tamponade eyes? SO is a liquid, whose dynamic fluid character is quite different from that of vitreous and aqueous. SO is lighter than water, patients are always told to keep a face down or prone position after PPV with SO tamponade to let the SO remain in the upper space of the eyeball, which will exert an upward push on the retina to the eyeball. Pan J found that IOP was lowest in patients sitting with face forward, and highest in the prone position [12]. This is not different than the postural IOP trend in normal eyes. Hoshi S studied the 24 h IOP fluctuation in the SO tamponade eyes [13]. He did not find difference in the diurnal behavior between SO eyes and normal eyes. These showed that the physiological characters might not change a lot in SO eyes. Not until we could develop an instrument that could measure CBPs under different positions, such as lateral decubitus, prone position, or sitting with face down, could we fully understand postural factors in IOP measurement in SO eyes and the diurnal fluctuation.

## References

1. Ichhpujani P, Jindal A, Jay Katz L (2009) Silicone oil induced glaucoma: a review. *Graefes Arch Clin Exp Ophthalmol* 247: 1585-1593.
2. Shen Y, Su X, Liu X, Miao H, Fang X, et al. (2016) Changes in intraocular pressure values measured with noncontact tonometer (NCT), ocular response analyzer (ORA) and corvis scheimpflug technology tonometer (CST) in the early phase after small incision lenticule extraction (SMILE). *BMC Ophthalmol* 16: 205.
3. Teke MY, Elgin U, Sen E, Ozdal P, Ozturk F (2014) Intravitreal silicone oil induced changes in corneal biomechanics. *Int Ophthalmol* 34: 457-463.
4. Zhang Y, Zheng L, Bian A, Zhou Q (2017) IOP measurement in silicone oil tamponade eyes by Corvis ST tonometer, Goldmann appplanation tonometry and non-contact tonometry. *Int Ophthalmol* 25.
5. Hong J, Xu J, Wei A, Deng SX, Cui X, et al. (2013) A new tonometer-the Corvis ST tonometer: clinical comparison with noncontact and Goldmann appplanation tonometers. *Invest Ophthalmol Vis Sci* 54: 659-665.
6. Jordanidou V, Hamard P, Gendron G, Labbé A, Raphael M, et al. (2010) Modifications in corneal biomechanics and intraocular pressure after deep sclerectomy. *J Glaucoma* 19: 252-256.
7. Ortiz D, Piñero D, Shabayek MH, Arnalich-Montiel F, Alió JL (2007) Corneal biomechanical properties in normal, post-laser in situ keratomileusis, and keratoconic eyes. *J Cataract Refract Surg* 33: 1371-1375.
8. Hager A, Loge K, Füllhas MO, Schroeder B, Grossherr M, et al. (2007) Changes in corneal hysteresis after clear corneal cataract surgery. *Am J Ophthalmol* 144: 341-346.
9. De Moraes CG, Hill V, Tello C, Liebmann JM, Ritch R (2012) Lower corneal hysteresis is associated with more rapid glaucomatous visual field progression. *J Glaucoma* 21: 209-213.
10. Hager A, Loge K, Kutschan A, Wiegand W (2008) The effect of cataract and vitreoretinal surgery on central corneal thickness and corneal hysteresis. *Klin Monbl Augenheilkd* 225: 207-211.
11. Woo SL, Kobayashi AS, Schlegel WA, Lawrence C (1972) Nonlinear material properties of intact cornea and sclera. *Exp Eye Res* 14: 29-39.
12. Pan J, Cheng D, Feng X, Zheng L, Dong Y, et al. (2017) Effect of body position on intraocular pressure in silicone oil tamponade eyes. *Retina* 3.
13. Hoshi S, Tamai M (1990) The diurnal variation of the intraocular pressure of vitrectomized eyes receiving instillation of silicone oil. *Nippon Ganka Gakkai Zasshi* 94: 281-285.