ORIGINAL ARTICLE

Validation of Aspiration while Varying Intraocular Pressure using Monitored Forced Infusion

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ABSTRACT

Purpose: The relationship between intraocular pressure (IOP) and actual aspiration has never been studied. In a previous study, we found that as IOP increased, efficiency also increased. We theorized that as IOP increases, aspiration rates may increase even at a fixed flow setting. **Setting:** John A. Moran Eye Center Laboratories, University of Utah, Salt Lake City, Utah, USA. **Design:** *In vitro* laboratory study. **Methods:** We validated the actual aspiration rates at varying IOP levels; system settings were tested from 30 to 110 mmHg at 20 mmHg intervals. Aspiration varied at 20, 35, and 50 mL/min. Torsional power was set to 60% and vacuum was set to 500 mmHg. The handpiece was placed into a balanced salt solution-filled testing chamber, and the pedal was depressed to the third position and held there for 60 s. The phacoemulsification pack drainage tube was cut and placed into a graduated cylinder to measure actual fluid volume. This was repeated 10 times for each setting. **Results:** Our results showed a positive linear relationship between IOP and aspiration. An increase in IOP increased actual flow beyond the actual setting at 20, 35, and 50 mL/min. **Conclusions:** As IOP increased, aspiration increased linearly. Thus, the real aspiration rate will be higher than the fixed setting as IOP is increased. This was a 25% range of actual flow over the IOP settings tested at 20 ml/min and 10% at 50 ml/min.

Key words: Aspiration, efficiency, flow rate, intraocular pressure, phacoemulsification

BACKGROUND/INTRODUCTION

Cataract surgery is the most commonly performed ambulatory surgery in the United States today.[1] Safe and effective use of phacoemulsification (phaco) technology for cataract removal requires understanding and optimizing the many settings that affect fluidics and efficiency. In previous phaco optimization studies, the Whitestar Signature and Whitestar Sovereign (Abbott Laboratories, Inc., Abbott Park, Illinois, USA) phaco systems have been used.[2-8] The Centurion® Vision System (Alcon Laboratories, Inc., Fort Worth, Texas, USA), a newer phaco system, which makes use of Active Fluidics™, has not been studied rigorously. In systems that employ gravity fluidics, bottle height determines the intraocular pressure (IOP) in the eye. Alternatively, the Centurion system allows surgeons to set IOP in place of bottle height. Active Fluidics™ was designed to deliver improved IOP stability during phaco. Sharif-Kashani *et al.* found that active fluidics has smaller amplitude occlusion break surges compared to both the Infiniti Vision System (Alcon Laboratories, Inc.) and the Whitestar system at all IOP levels tested between 40 and 65 mmHg.[9] Therefore, active fluidics may be safer than gravity fluidics in surgery by reducing the risk of post-occlusion surge.

Efficiency is affected by three main factors: Flow, vacuum, and phaco tip movement.[10] Inflow is something that generally equals outflow in a tight system and is set by the machine.

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Vacuum peak, when reached after occlusion, becomes a force in itself to remove lens particles.[11] In a previous study, we found that increasing IOP in this new IOP controlled machine led to increasing efficiency, the inverse of the time necessary to remove nuclear material.[12] Since phaco tip type and all other settings were constant in the study, this finding was not expected. One possible explanation was that actual flow was not constant as IOP was increased. We have repeatedly shown that increased flow generally equals increased efficiency, thus such a finding would explain why increased IOP increased efficiency.

In this follow-up study, we investigated the relationship between IOP and actual machine aspiration flow rates. We hypothesized that by increasing IOP, the centurion active fluidics mechanism also increased the actual flow rate, even when aspiration is preset by the surgeon.

MATERIALS AND METHODS

We conducted the study with the CENTURION Vision System with the Ozil handpiece (Alcon Surgical, Fort Worth, Texas, USA) and 0.9 mm bent phaco tips with a 30° bevel. IOP system settings were tested from 30 to 110 mmHg, at 20 mmHg intervals. Aspiration varied at 20, 35, and 50 mL/min. Torsional power was set to 60% and vacuum was set to 500 mmHg. After the handpiece was placed into a testing chamber filled with balanced salt solution, the pedal was immediately depressed to the third position and held there for 60 s. The phaco pack drainage tube was cut and placed into a graduated cylinder to measure actual fluid volume. This was repeated 10 times for each setting.

Statistical analysis

The aspiration values were recorded and were normalized as a ratio of the mean for the combined results at that setting. These values were used to calculate a mean and standard deviation. Linear regression was performed and used to compare the aspiration for the different groups tested. The calculated R^2 was used to show any significant change in the aspiration with IOP variation. $P < 0.05$ was considered statistically significant. All statistical analyses were performed using GraphPad Prism (GraphPad Software, Inc., La Jolla, California, USA).

RESULTS

Results of the trials showed a positive linear relationship between IOP and aspiration. An increase in IOP increased actual flow at the setting of 20 mL/min ($R^2 = 0.99$, $P = 0.0004$, Figure 1), 35 mL/min ($R^2 = 0.78$, $P = 0.046$, Figure 2), and 50 mL/min ($R^2 = 0.92$, $P = 0.0092$, Figure 3). Flow set at 20 mL/min had a range of actual flow from 17.0 to 22.0 mL/min, depending on the IOP setting. Similarly, a

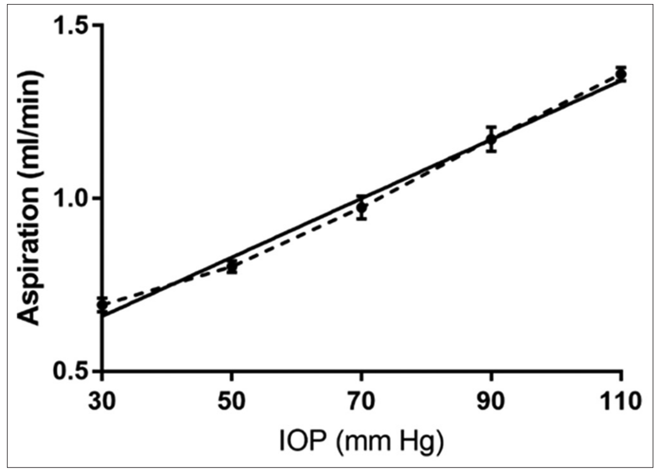

Figure 1: Measured aspiration rates while varying intraocular pressure from 30 to 110 mmHg with a preset aspiration of 20 ml/min

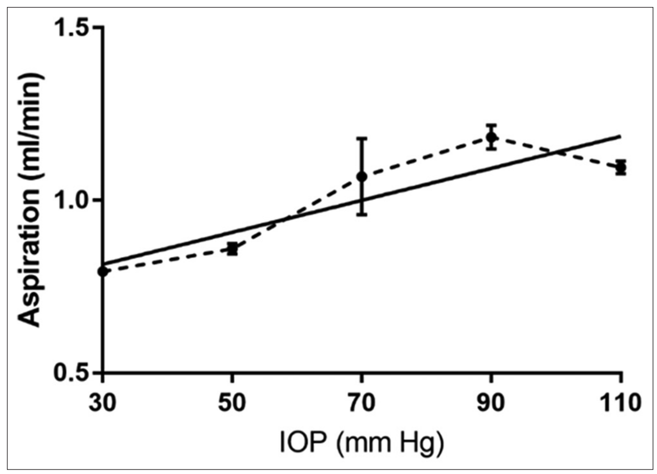

Figure 2: Measured aspiration rates at varying intraocular pressure from 30 to 110 mmHg with a preset aspiration of 35 ml/min

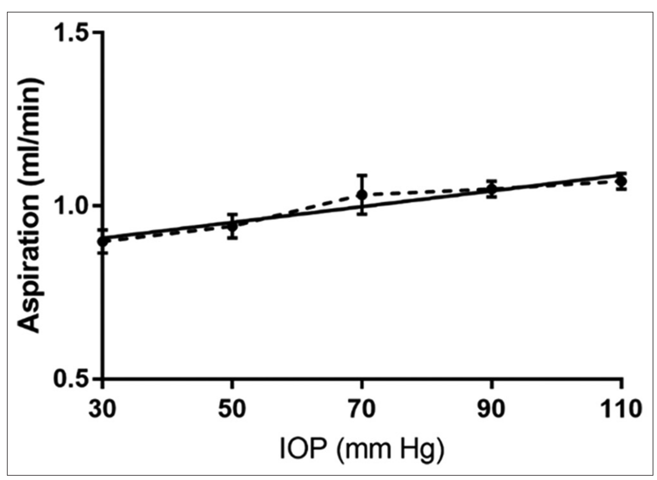

Figure 3: Measured aspiration rates at varying intraocular pressure from 30 to 110 mmHg with a preset aspiration of 50 ml/min

flow of 35 mL/min had a range of 33.5–37.0 mL/min; and a flow of 50 mL/min varied from 48.5 to 50.5 mL/min.

We also noted that the flow difference at increasing vacuum was greater at lower flow rates. At a flow rate of 20, there was a 29% increase in average flow from the lowest IOP setting to the highest IOP setting, at 35 an average increase of 10% from low IOP to high IOP, and at 50 a 5% increase from low to high IOP.

DISCUSSION

Previously, we found that increasing IOP led to increasing efficiency.[12] We hypothesized that the efficiency increase was actually due to an increase in aspiration even though the phaco machine flow setting had not changed. Our findings in this study help to confirm this hypothesis by documenting a linear relationship to actual aspiration flow rates, which depended on the IOP levels. Although this linear increase in aspiration level with increasing IOP level would likely increase efficiency, these increases measured at 5–29%, and therefore, we were surprised that our efficiency times increased as much as they did in the prior study. In this previous study from our laboratory, in which aspiration was set at 35 ml/min, efficiency at an IOP of 30 was 1.85 seconds, and efficiency at an IOP at 110 was 1.07 s.[12] This showed an increase in efficiency of 57%, while the increased flow from increasing IOP at the same setting exhibited in this study was 10%. This leaves a 47% increase in efficiency in our prior study that cannot be explained by increasing IOP alone, assuming the relationship is linear. Although we cannot directly compare these two studies, the results are relevant to both and strongly suggest that increasing IOP results in increased efficiency beyond increases in flow.

Other possible contributing factors that could explain the remaining 47% increase in efficiency could include how IOP effects the time it takes for a particle acquisition, how increasing IOP changes the shape of the chamber itself and thus the aspiration and vacuum vortexes within the chamber, and how IOP changes the rate of particle extracted by increasing external forces, forcing the particle into the phaco tip. One other possibility is that vacuum is also not constant and increases with increasing IOP just like flow does. All of these hypotheses are interesting and could be tested with follow-up studies.

This study is limited by the *in vitro* environment. The results might be more applicable to *in vivo* cataract surgery given that this study is testing the mechanical properties of the machine more than the testing environment. The results of our study suggest that surgeons should realize that increasing IOP also increases flow no matter what the machine setting might be. Careful attention should be given at low flow settings where this effect was more significant. Moving forward, additional research should be conducted to determine the effect of increasing IOP on vacuum, how this increased flow effect is impacted at different vacuum levels, and on particle acquisition time.

CONCLUSION

The results of this study clearly show that increasing IOP also increases flow, with the effect greater at lower flow rates.

FUNDING

This study was supported in part by an unrestricted grant from Research to Prevent Blindness, Inc., New York, New York, USA, to the Department of Ophthalmology and Visual Sciences, University of Utah, Salt Lake City, Utah, USA. Dr. Zaugg has an Achievement Rewards for College Scientists Foundation Scholar (ARCS Foundation Utah, Salt Lake City, Utah, USA).

ACKNOWLEDGMENTS

Susan Schulman provided editorial and manuscript preparation assistance.

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How to cite this article: Jensen JD, Christensen M, Boulter T, Vegunta S, Ha L, Ta B, Zaugg B, Olson RJ, Stagg BC, Bernheisel A, Barlow WR, Pettey JH. Validation of Aspiration while Varying Intraocular Pressure using Monitored Forced Infusion. Clin Res Ophthalmol 2018;1(1):1-4.